THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EVERYDAY PRACTICAL ELECTRONICS

Vol.34 No.12

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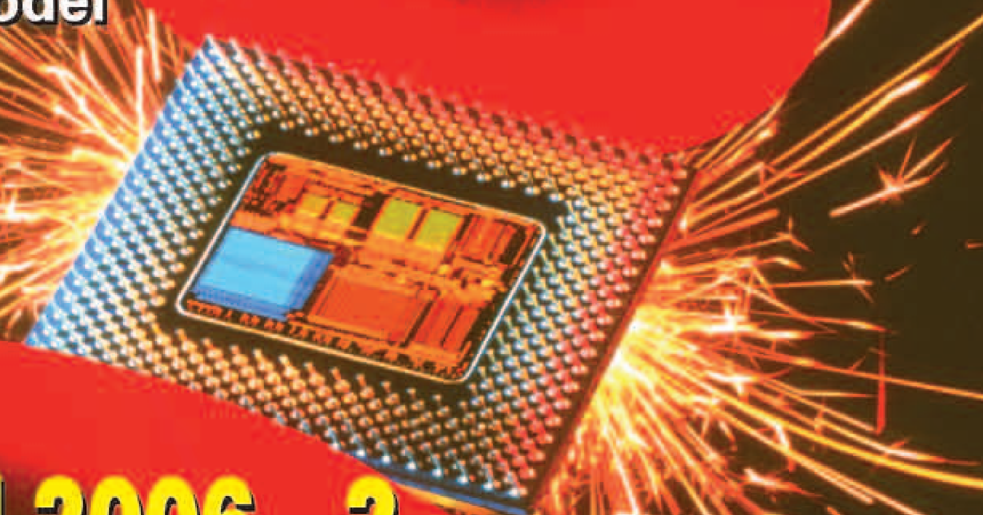

PLUS

TEACH-IN 2006 - 2
Circuit Diagrams,
Series and Parallel Circuits,
Analogue and Digital Meters,
Construction Techniques

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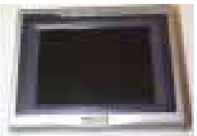
Printed in the UK

Colour CCTV camera, 8mm lens, 12vdc200m a 582X628 Res 380 lines Automatic aperture lens Mirror function PAL Back Light Comp MLR, 100x40x40mm ref EE2 £75.90

Built in Audio .15lux CCD camera 12vdc 200ma 480 lines s/n ratio >48 db 1v P-P output 110x60x50mm ref EE1 £108.90

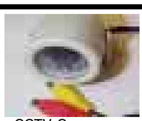
Metal CCTV camera housings for internal or external use. Made from aluminium and plastic they are suitable for mounting body cameras in.Available in two sizes 1-100x70x170mm and 2-100x70x280mm Ref EE6 £22 EE7 £26 Multi position brackets Ref EE8 £8.80



Excellent quality multi purpose TV/ TFT screen, works as just a LCD colour monitor with any of our CCTV cameras or as a conventional TV ideal for use in boats and caravans 49.75mhz-91.75mhz VHF channels 1-5, 168.25mhz-222.75mhz VHF channels 6-12, 471.25mhz-869.75mhz, Cable channels 112.325mhz-166.75mhz Z1-Z7, Cable channels 224.25mhz-446.75mhz Z8-Z35 5" colour screen,Audio output 150mW,Connections, external aerial, earphone jack, audio/video input,12vdc or mains, Accessories supplied Power supply Remote control Cigar lead power supply Headphone Stand/bracket. 5" model £139 Ref EE9,

Self cocking pistol plcr002 crossbow with metal body.· Selfcocking for precise string alignment Aluminium alloy construction High tec fibre glass limbs Automatic safety catch Supplied with three bolts Track style for greater accuracy Adjustable rear sight 50lb draw weight 150ft sec velocity Break action 17" string 30m range £23.84 Ref PLCR002

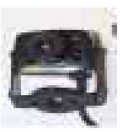
Fully cased **IR light source** suitable for CCTV applications. The unit measures 10x10x150mm, is mains operated and contains 54 infra red LEDs. Designed to mount on a standard CCTV camera bracket. The unit also contains a daylight sensor that will only activate the infra red lamp when the light level drops below a preset level. The infrared lamp is suitable for indoor or exterior use, typical useage would be to provide additional IR illumination for CCTV cameras. £53.90 ref EE11



Colour CCTV Camera measures 60x45mm and has a built in light level detector and 12 IR leds .2 lux 12 IR leds 12vdc Bracket Easy connect leads £75.90 Ref EE15

A high quality external colour CCTV camera with built in Infra red LEDs measuring 60x60x60mm Easy connect leads colour Waterproof PAL 1/4" CCD542x588 pixels 420 lines .05 lux 3.6mm F2 78 deg lens 12vdc 400ma Built in light level sensor. £108.90 Ref EE13

3km Long range video and audio link complete with transmitter, receiver, 12.5m cables with pre fitted connectors and aerials. Acheive up to 3km. Cameras not included Ideal for stables, remote buildings etc. Mains power required £299



A small colour CCTV camera just 35x28x30mm Supplied with bracket, easy connect leads. Built in audio. Colour 380 line res, PAL 0.2 lux +18db sensitivity Effective pixels 628x582 6-12vdc Power 200mw £39.60 Ref EE16

Complete wireless CCTV sytem with video. Kit comprises pinhole colour camera with simple battery connection and a receiver with video output. 380 lines colour 2.4ghz 3 lux 6-12vdc manual tuning Available in two versions, pinhole and standard.£79 (pinhole) Ref EE17, £86.90 (standard) Ref EE18

Peltier module. Each module is supplied with a comprehensive 18 page Peltier design manual featuring circuit designs, design information etc etc. The Peltier manual is also available separately Maximum watts 56.2 40x40mm Imax 5.5A Vmax 16.7 Tmax (c- dry N2) 72 £32.95 (inc manual) REF PELT1, just manual £4.40 ref PELT2

GASTON SEALED LEAD ACID BATTERIES

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3.4AH 12V @ £8.80 GT1234
7AH 12V @ £8.80 GT127
17AH 12V @ £19.80 GT1217

All new and boxed, bargain prices. Good quality sealed lead acid batteries

COMPAQ 1000mA 12vdc power supplies, new and boxed. 2 metre lead DC power plug 2.4mmx10mm £5.25 each, 25+ £3.50 100+£2.50

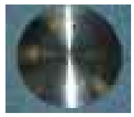
1.2ghz wireless receiver Fully cased audio and video 1.2ghz wirelessreceiver190x140x30mm, metal case, 4 channel, 12vdc Adjustable time delay, 4s, 8s, 12s, 16s. £49.50 Ref EE20

The smallest PMR446 radios currently available (54x87x37mm). These tiny handheld PMR radios look great, user friendly & packed with features including VOX, Scan & Dual Watch. Priced at £59.99 PER PAIR they are excellent value for money. Our new favourite PMR radios! Standby: - 35 hours Includes:- 2 x Radios, 2x Belt Clips & 2 x Carry Strap £59.95 Ref ALAN1 Or supplied with 2 sets of rechargeable batteries and two mains chargers £93.49 Ref Alan2

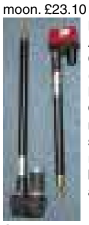
The TENS mini Microprocessors offer six types of automatic programme for shoulder pain, back/neck pain, aching joints, Rheumatic pain, migraines headaches, sports injuries, period pain. In fact all over body treatment. Will not interfere with existing medication. Not suitable for anyone with a heart pacemaker. Batteries supplied. £21.95Ref TEN327 Spare pack of electrodes £6.59 Ref TEN327X

Dummy CCTV cameras These motorised cameras will work either on 2 AA batteries or with a standard DC adapter (not supplied) They have a built in movement detector that will activate the camera if movement is detected causing the camera to 'pan' Good deterrent. Camera measures 20cm high, supplied with fixing screws. Camera also has a flashing red led. £10.95 Ref CAMERAB

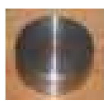
INFRA RED FILM 6" square piece of flexible infra red film that will only allow IR light through. Perfect for converting ordinary torches, lights, headlights etc to infrared output using standard light bulbs Easily cut to shape. 6" square £16.50 ref IRF2 or a 12" sq for £34.07 IRF2A



THE TIDE CLOCK These clocks indicate the state of the tide,Most areas in the world have two high tides and two low tides a day, so the tide clock has been specially designed to rotate twice each lunar day (every 12 hours and 25 minutes) giving you a quick and easy indication of high and low water. The Quartz tide clock will always stay calibrated to the moon. £23.10 REF TIDEC



LINEAR ACCTUATORS 12-36VDC BUILT IN ADJUSTABLE LIMIT SWITCHES POWDER COATED 18" THROW UP TO 1,000 LB THRUST (400LB RECOMMENDED LOAD) SUPPLIED WITH MOUNTING BRACKETS DESIGNED FOR OUTDOOR USE These brackets originally made for moving very large satellite dishes are possibly more suitable for closing gates, mechanical machinery, robot wars etc. Our first sale was to a company building solar panels that track the sun! Two sizes available, 12" and 18" throw. £32.95 REF ACT12,

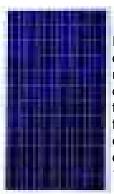


Samarium magnets are 57mm x 20mm and have a hole (5/16th UNF) in the centre and a magnetic strength of 2.2 gauss. We have tested these on a steel beam running through the offices and found that they will take more than 170lbs (77kgs) in weight before being pulled off. With keeper. £21.95 REF MAG77

New transmitter, receiver and camera kit. £69.00

Kit contains four channel switchable camera with built in audio, six IR leds and transmitter, four channel switchable receiver, 2 power supplies, cables, connectors and mounting bracket. £69.00 Wireless Transmitter Black and white camera (75x50x55mm) Builtin 4 channel transmitter (switchable) Audio built in 6 IR Leds Bracket/ stand Power supply 30 m range **Wireless Receiver** 4 channel (switchable) Audio/video leads and scart adapter Power supply and Manual £69.00 ref COP24

This miniature **Stirling Cycle Engine** measures 7" x 4-1/4" and comes complete with built-in alcohol burner. Red flywheels and chassis mounted on a green base, these all-metal beauties silently running at speeds in excess of 1,000 RPM attract attention and create awe wherever displayed. This model comes completely assembled and ready to run. £106.70 REF SOL1



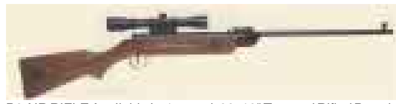
High-power modules using 125mm square multi - crystal silicon solar cells with bypass diode Anti reflection coating and BSF structure to improve cell conversion efficiency: 14%. Using white tempered glass, EVA resin, and a weatherproof film along with an aluminum frame for extended outdoor use. system Lead wire with waterproof connector. 80 watt 12v 500x1200 £315.17, 123w 12vdc 1499x662x46 £482.90
165 w 24v 1575x826x46mm £652.30

Ultra-compact, lightweight, easy to use and comfortable to hold, the new NVMT is unique for a night scope in offering a tactile, suregrip plastic bodyshell and, for extra protection/grip, partial rubber armouring. Currently the top of the range model, the NVMT G2+ features a 'commercial' grade* Gen 2+ Image Intensifier Tube (IIT). The NVMT has a built-in, powerful Infrared (IR) Illuminator for use in very low light/total darkness. Power for the scope and IR is provided by 1 x 3V Lithium CR123A battery (not supplied). A green LED next to the viewfinder indicates when the Image Intensifier Tube is switched on while a red LED indicates when the IR Illuminator is switched on.Type Gen Weight Size Lens Mag 2x, Weight 400g, 125x82x35mm angle of view 30 deg, built in infra red, rang 3 - 400m, supplied with batteries £849 ref COB24023.

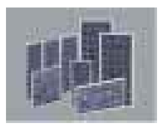
55 - 200 WATT INFRA RED TORCHS

Search guard 1 infrared torch Plastic bodied waterproof infrared rechargeable lamp. 100mm diameter lens, 200mm body length. 55 watt bulb, 1,000,000 candle power (used as an indication of relative power) Supplied complete with a 12v car lighter socket lead/charger and a 240v mains plug in charger. £49 REF sguard 1. Also available, 70watt @ £59, 100 watt @ £79, 200watt @ £99.

AIR RIFLES FROM £24.70



B2 AIR RIFLE Available In.177 and .22• 19" Tapered Rifled Barrel• Adjustable Rear Sight• Full Length Wooden Stock• Overall Length 43" approxBarrel Locking Lever • Also available in CARBINE Grooved for Telescopic Sight model with 14" barrel - no front sight for use with scope. Weight approximately 6lbs Extremely Powerful .22 £28.90, .177 £24.70, pellets (500) £2.55, sights 4x20 £6.80, 4x28 £15.32 Other models available up to £250 www.airpistol.co.uk



12V SOLAR PANELS AND REGULATORS
9 WATT £58.75
15 WATT £84.25
22 WATT £126.70
Regulator up to 60 watt £21.25
Regulators up to 135 watt £38.25

The combination of multi-crystal cells and a high-reliability module structure make this series of solar panels the ideal solar module. For large-scale power generation hundreds or even thousands of modules can be connected in series to meet the desired electric power requirements. They have a high output, and highly efficient, extremely reliable and designed for ease of maintenance. Separate positive negative junction boxes and dual by-pass diodes are a few examples of some of its outstanding features. Supplied with an 8 metre cable. Perfect for caravans, boats, etc. Toughened glass.

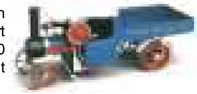
LOCK PICK SETS 16, 32 AND 60 PIECE SETS

This set is deluxe in every way! It includes a nice assortment of balls, rakes, hooks, diamonds, two double ended picks, a broken key extractor, and three tension wrenches. And just how do you top off a set like this? Package it in a top grain leather zippered case. Part: LP005 - Price £45.00

This 32 piece set includes a variety of hooks, rakes, diamonds, balls, extractors, tension tools ... and comes housed in a zippered top grain leather case. If you like choices, go for this one! Part: LP006 - Price £65.00

If your wants run toward the biggest pick set you can find, here it is. This sixty piece set includes an array of hooks, rakes, diamonds, balls, broken key extractors, tension wrenches, and even includes a warded pick set! And the zippered case is made, of course, of the finest top grain leather. First Class! Part: LP007 - Price £99.00

Mamod steam roller, supplied with fuel and everything you need (apart from water and a match!) £85 REF 1312 more models at www.mamodspares.co.uk



Mamod steam roller, supplied with fuel and everything you need (apart from water and a match!) £130 REF 1318 more models at www.mamodspares.co.uk

PEANUT RIDER STIRLING ENGINE This all metal, black and brass engine with red flywheel is mounted on a solid hardwood platform. comes complete with an alcohol fuel cell, extra wick, allen wrenches, and Owner's Manual.Specifications: Base is 5-1/4" x 5-1/4", 4" width x 9" height, 3/4" stroke, 3-1/2" flywheel £141.90

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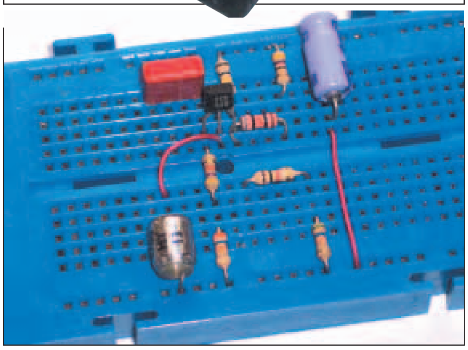

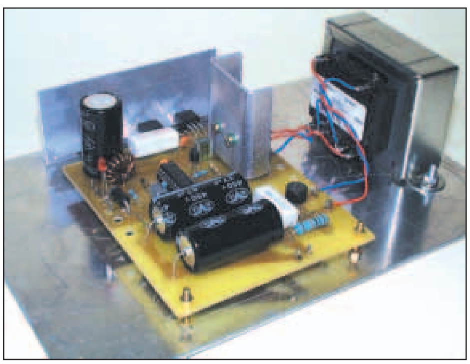

Projects and Circuits

Series and Features

Regulars and Services

Our January 2006 issue will be published on Thursday, 8 December 2005. See page 819 for details

NEXT MONTH

EVERYDAY PRACTICAL ELECTRONICS

★ SAME MAGAZINE
★ SAME PRICE ★ NEW LOOK
★ NEW LOGO ★ NEW PAPER
★ NEW COLOUR THROUGHOUT
★ DON'T MISS IT ★

Tiptronic – Style Gear Indicator

Do you know what gear your car is in at any given time? "Just look at the gear stick", you say. Actually it's not that easy, especially if you have a 4-speed automatic or 5 or 6-speed manual gearbox. And what if you ride a motorbike? So you need the Gear Indicator – it will give you the answer on a digital readout.

Indicates up to nine gears, neutral indication, reverse indication, easy gear calibration, adjustable parameters, display dimming, straightforward to fit.

Ambilux

In Techno Talk *of May '05, reference was made to an ambient-sensing light display known as the Stock Orb. It was quoted as being an ornament that glows in various colours depending on a number of external factors. These factors ranged from sensing the surrounding temperature, to the ever-changing ups and downs of values on the Stock Market. The concept caused the author to slip on his thinking cap, yet again!*

The design described here is a much simplified version of what the Stock Orb can probably do, using just a handful of components on a small printed circuit board. As presented, it simply interfaces to a rudimentary temperature sensor and controls five coloured l.e.d.s, conventional or super-bright. Its ultimate use and interface to other sensors is up to the ingenuity of the reader, although some ideas are offered.

Current Clamp Adaptor

Looking for a current clamp meter that won't break the bank? Here's a simple clamp meter adaptor that you can build for about £15. it plugs into a standard digital multimeter and can measure both AC and DC currents without the need to break the circuit under test. It will measure DC curent from 1A to 900A (yes that is nine hundred amps!) and AC current to 630A at up to 20kHz, depending on the meter's response.

Sunset Switch

Want to switch on an appliance at dusk and off again after a few hours or at dawn? This sunset switch can do this automatically for you. It is ideal for security and garden lighting.

Switches up to 6A of mains power at a preset darkness level, optional time out, four timeout selections, manual overide.

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see page 863

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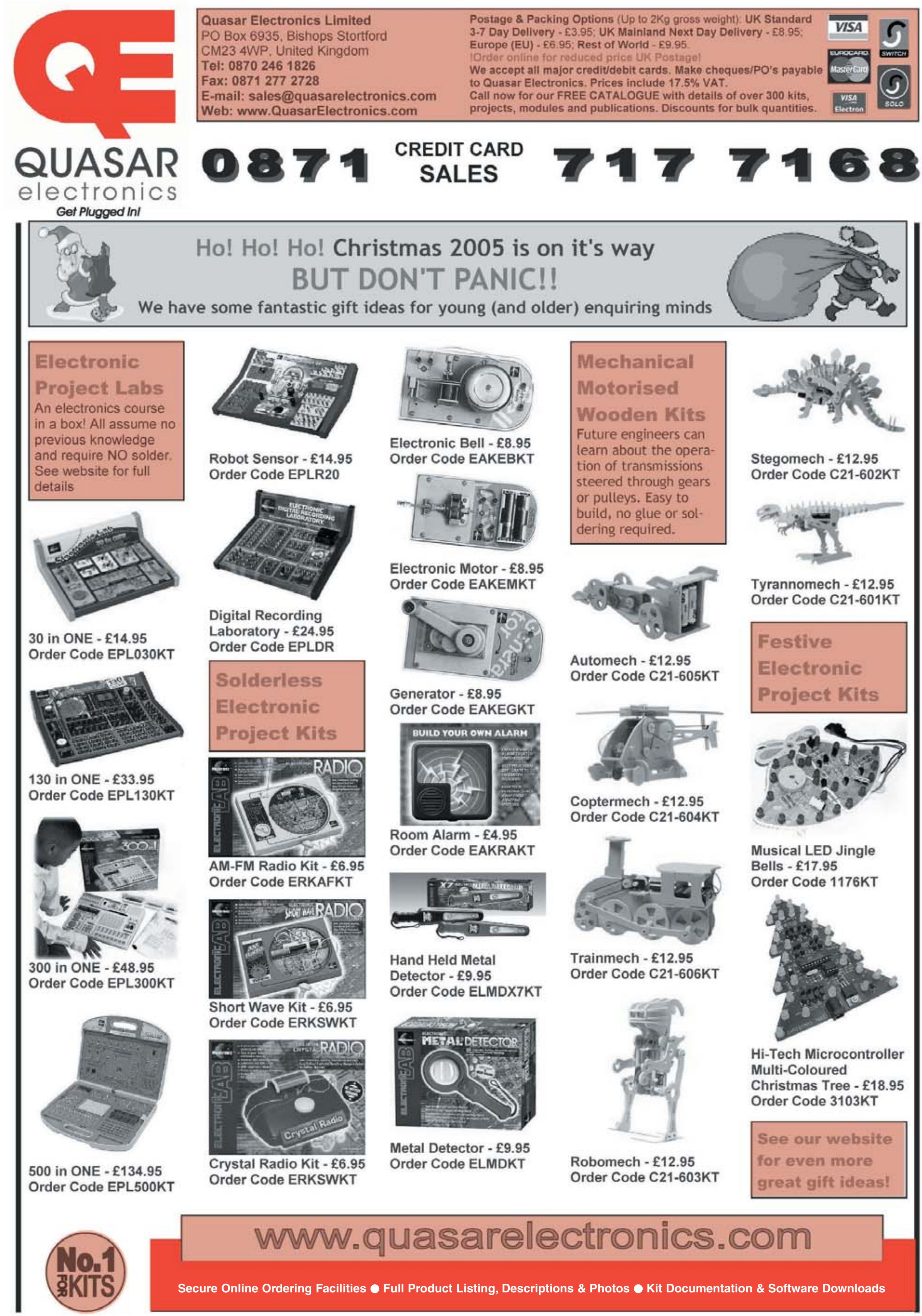

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(*Some projects are copyright)

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- Efficient quartz controlled microcontroller pulse generation.
- Full kit with headphones & all hardware

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- 8MHz 68000 16-BIT BUS
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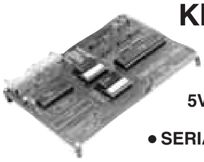

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- **ON BOARD 5V REGULATOR**
- **PSU £6.99**
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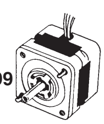

MD100..Std 100 step..£9.99
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- SIMPLE TO BUILD
- HIGH POWER OUTPUT
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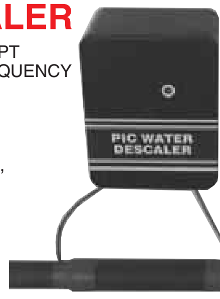

An affordable circuit which sweeps the incoming water supply with variable frequency electromagnetic signals. May reduce scale formation, dissolve existing scale and improve lathering ability by altering the way salts in the water behave.
Kit includes case, P.C.B., coupling coil and all components.
High coil current ensures maximum effect. L.E.D. monitor.

KIT 868 .... £22.95 POWER UNIT......£3.99

MICRO PEsT SCARER

Our latest design – The ultimate scarer for the garden. Uses special microchip to give random delay and pulse time. Easy to build reliable circuit. Keeps pets/pests away from newly sown areas, play areas, etc. uses power source from 9 to 24 volts.

- **RANDOM PULSES**
- **HIGH POWER**
- **DUAL OPTION**

Plug-in power supply £4.99

KIT 867. . . . .£19.99
KIT + SLAVE UNIT. £32.50

WINDICATOR

A novel wind speed indicator with LED readout. Kit comes complete with sensor cups, and weatherproof sensing head. Mains power unit £5.99 extra.

KIT 856. . . . .£28.00

★ TENS UNIT ★

DUAL OUTPUT TENS UNIT

As featured in March '97 issue.

Set of 4 spare electrodes **£6.50**

Magenta have prepared a FULL KIT for this. excellent new project. All components, PCB, hardware and electrodes are included.
Designed for simple assembly and testing and providing high level dual output drive.

KIT 866. . Full kit including four electrodes £32.90

1000V & 500V INSULATION TESTER

Superb new design. Regulated output, efficient circuit. Dual-scale meter, compact case. Reads up to 200 Megohms.
Kit includes wound coil, cut-out case, meter scale, PCB & ALL components.

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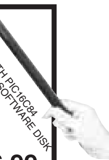

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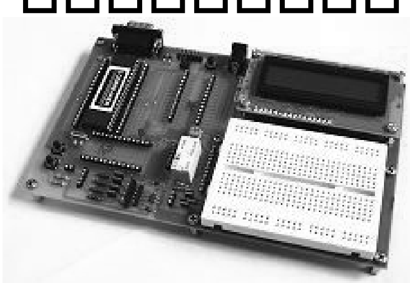

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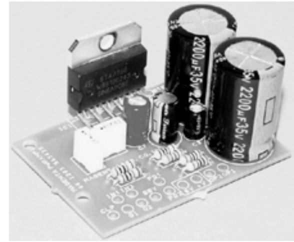

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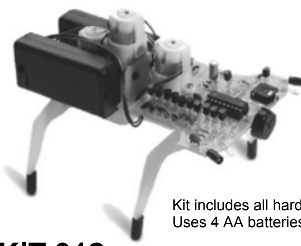

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New Logo

The title of *EPE* and the logo have gone through a number of changes over the past 35 years. The last major change was back in November 1992 when we added the *Practical* bit to *Everyday Electronics*. It has stood the test of time fairly well but now looks rather dated and from next month we will introduce a new logo – see above – to go with our higher quality paper and full colour throughout the magazine. We feel the new logo and new presentation of the editorial pages will add to the visual appeal of the magazine and take us forward into the next 35 years. The next issue will be a bumper issue with all the regular *EPE* articles, but they will be presented in a more modern fashion.

Following last month's Editorial one or two readers have contacted us worried that we will "throw the baby out with the bathwater" but please be assured that we have no intention of changing the type of articles or projects we publish, except, as always, we will endeavor to bring you as wide a range of projects as possible. We will continue to give full constructional information for each project, together with all the relevant circuit data etc.

The line-up for our next issue includes a very useful Current Clamp which allows a multimeter to measure a.c. and d.c. current from 1A to over 600A without breaking the circuit; a "Tiptronic Style" Gear Indicator for use in cars and motocycles; a Sunset Switch with optional timeout for security and garden lighting, plus Ambilux from John Becker – see page 819 for a description of this fascinating ambient-sensing light display.

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Watch out for the new logo on the bookstalls on December 8th.

Mike Kenward

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Constructional Project

Vehicle Frost Box Mk2

Malcolm Wiles

With winter approaching again, give yourself extra warning of treacherous road conditions

WHEN the author first saw the *Vehicle Frost Box* by Steve Dellow in the Jan 2000 *EPE*, he was immediately taken with it, and soon knocked one up and installed it in his car.

Steve's *Frost Box* was designed to indicate the external temperature by means of a dual colour red/green l.e.d., and warn when black ice on the road was likely. The l.e.d. was designed to show green above 4ºC (when ice formation is presumably unlikely), red between 0ºC and 4ºC, and flash alternately green and red below 0ºC. The temperature sensor was nothing more complicated than a simple signal diode.

Several things about the project seemed interesting: the economy of the temperature sensor (components don't come much cheaper than 1N4148 diodes!), the simplicity and effectiveness of the red/green diode display, and the cleverness of the design in contriving three different display patterns corresponding to different temperatures, were all factors. Plus the author's ageing car was not equipped with a thermometer, so it was a useful project anyway.

Cold History

The *Frost Box* functioned well for four years, till one cold frosty morning recently the indicator l.e.d. showed green when it should clearly have indicated an ice alert. A quick inspection revealed that the sensor, normally located on a suspension component near a back wheel, had completely disappeared, presumably eventually succumbing to some flying road debris after four years of valiant service in this hostile environment. The leads to the missing component were dangling and shorting, producing the erroneous display.

Not a serious problem, because it would be easy and cheap enough to replace the sensor. However, one feature of the *Frost Box* design had always been a bit unsatisfactory, which was that no way was provided to adjust the temperature ranges over which the three different l.e.d. displays (green, red, red/green alternating) would operate. Once the circuit had been calibrated with freezing point, the other ranges were pre-determined.

The original article had indicated that there should be a temperature range of about 4ºC above freezing point where the display would be red before it became green. With the author's circuit and components this range proved to be nearer 2ºC, which was narrower than ideally he would have liked. Because of the intricate way in which the components involved in producing the display interacted, it was not easy to change the values of some components a little to extend the "red" temperature range without stopping the circuit functioning entirely.

Ice PIC

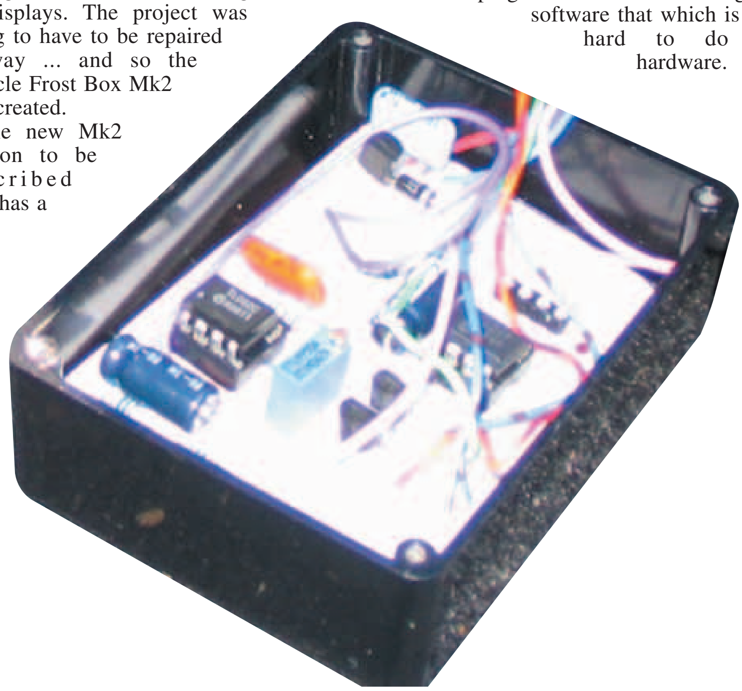
As it happened, at the same time that the old sensor died the author was playing with some of the PIC12F devices (see *Pic n' Mix* Dec '04). The idea thus occurred that the PIC12F675, which could be configured with an ADC (analogue-to-digital converter) and a couple of I/O (input/output) pins, was almost ideally suited to the task of taking the sensor output and producing a more varied and configurable set of displays. The project was going to have to be repaired anyway ... and so the Vehicle Frost Box Mk2 was created.

The new Mk2 version to be described now has a total repertoire of seven different display patterns on a red/green dual colour l.e.d. It shows green when the temperature is above 5·4ºC, and so ice formation on the road is very unlikely, and flashes alternately red and green when the temperature is 0ºC or below.

Between these extremes, five more displays indicate intermediate temperatures in steps of approximately 1ºC. These ranges, and indeed the display patterns themselves, may be easily changed to suit individual preferences by making a few very simple changes to the PIC software.

The author is a bit apologetic about solving his adjustment problem by effectively throwing brute force power at it, and has some sympathy with those readers who occasionally complain that these days it seems to be "PICs with everything". He wishes that he had the skill to fix it with elegant logic, but regrettably he does not.

He can, however, write software a bit, having spent the last 35 years or so doing it for a living. So this design represents a pragmatic solution – doing in software that which is too hard to do in hardware.



Circuit Description

As explained in the original article, the voltage drop across a semiconductor junction depends both on its temperature and the current flowing through it. So if the current is kept constant, this voltage drop can be used as a measure of temperature. Within reasonable limits the dependency is linear, and changes by approximately −2·5 millivolts per degree Celsius (meaning that as the temperature increases, the voltage drop decreases).

The complete circuit diagram for the *Vehicle Frost Box Mk2* is shown in Fig 1. The circuit around op.amps IC1a and IC1b is almost identical to the original version. Op.amp IC1a is wired in conventional negative feedback style, with sensor diode D1 in the feedback loop. The non-inverting input of IC1a is clamped at half the supply voltage (2·5V) by the potential divider action of resistors R1 and R2.

as an indication of different temperatures.

A 4-way s.i.l. (single-in-line) connector TB1, in the usual *EPE* pin configuration, is provided to allow in-circuit programming of the PIC. If this feature is not needed, the connector may be omitted, and R8 and D2 may be replaced with a wire link. The PIC's internal oscillator is used, so no external clock components are necessary.

As explained in the next section, the circuit employs quite a high level of amplification. This means that it is necessary to keep things as stable as possible, otherwise any noise will be amplified to intrusive levels at the output. IC1 and IC2 are therefore provided with generous levels of power supply decoupling (C3 and C2 respectively).

Also, although the PIC would be capable of driving the l.e.d. display directly from its I/O pins, in theory allowing a further simplification of the circuit, it was found that the voltage regulation provided

temperatures in the range from 5ºC or above down to 0ºC or lower. The sensor (diode D1) varies at 2·5mV/ºC. So theoretically it needs to be amplified by a factor of (3·6 × 1000)/(2·5 × 5) = 288.

The actual amplification in the circuit (set by the ratio R7/R4) is a little less than this at 220, to allow some safety margin for component tolerances etc. This means that each degree Celsius corresponds to 220 × 0·0025 = 0·55V at AD2.

The ADC in IC2 has a resolution of 10 bits, or 1024 raw ADC units. In the software the raw A/D output is divided by four, both to give a more easily manageable number in the range 0 to 255, and the least significant two bits of the A/D conversion are mostly noise anyway.

This number range 0 to 255 is called A/D units from now on. With the A/D conversion being made relative to the supply voltage of 5V, each volt corresponds to 256/5 = 51·2 A/D units, and each degree C corresponds to 0·55 x 51·2 = 28·2 A/D units.

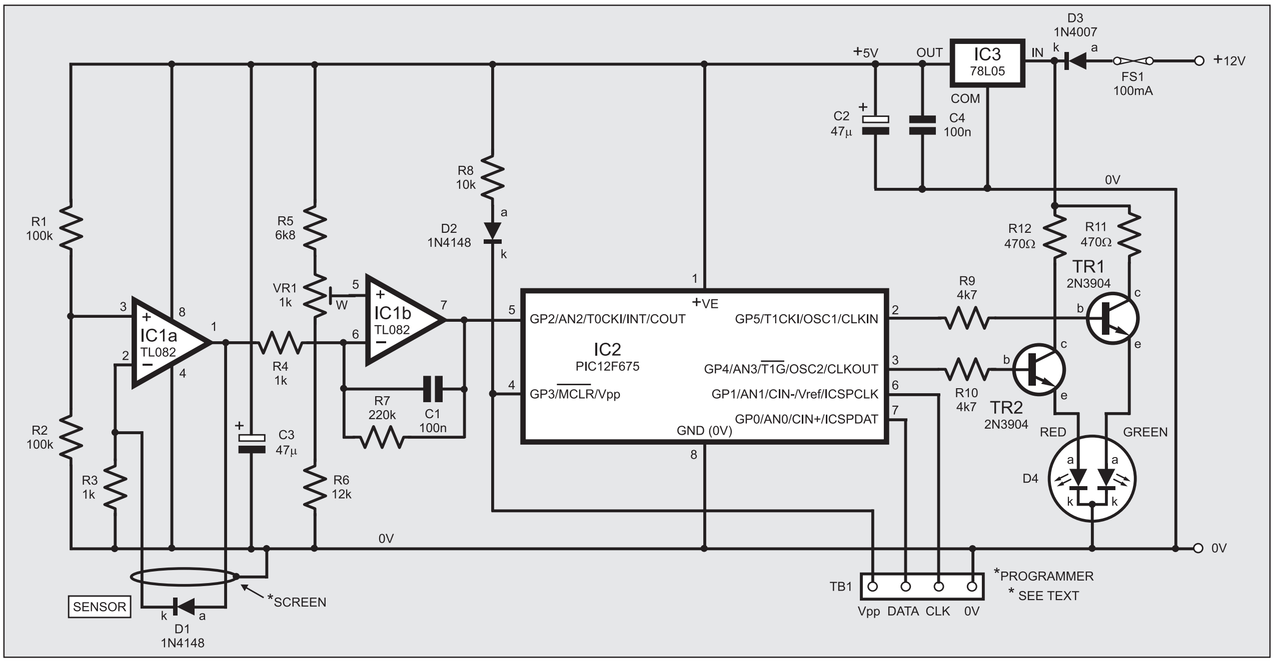


Fig.1. Full circuit diagram for the Vehicle Frost Box Mk2. Diode D1 is the frost/ice detector

The feedback ensures that the voltage at the inverting input (pin 2) will be kept at the same value by changes in IC1a's output voltage as necessary. So the current through D1 is kept constant at 2·5/R3 = 2·5mA, and the voltage at the output of IC1a will be the sum of the inverting input voltage plus the varying diode drop voltage (around 3·1V). IC1a's output voltage is inverted and amplified by the standard circuit around IC1b. Capacitor C1 rolls off any high frequency noise present.

The voltage at the output of IC1b is taken straight to pin 5 of IC2, a PIC12F675 microcontroller. Pin 5 is configured as AD2 (an ADC input). Pins 2 and 3 are configured as digital outputs, and are used to drive the green and red halves of the l.e.d. (D4) via transistors TR1 and TR2 and associated resistors R9 to R12. Depending on the voltage present at pin 5, software in the PIC generates a variety of different displays on the l.e.d.s

by IC3 is to a small extent dependent on the current being supplied. The l.e.d. supply current of 10mA or so would be the major demand on regulator IC3, and the supply voltage was found to vary by a few millivolts depending on whether an l.e.d. was turned on or not.

This translated to a voltage difference of 100mV or so at AD2. While not a showstopper (a 2% error in an overall level of 5V), it was preferred to minimise this by retaining TR1 and TR2 to drive the l.e.d.s, and obtaining the l.e.d. supply current from an unregulated source upstream from IC3.

Design Calculations

With a 5V supply, the TL082 op.amp used for IC1 has an output voltage swing from about 0·7V to 4·3V, an available range of about 3·6V. This swing is used to represent a temperature range of about 5ºC, so that the l.e.d. display will indicate

Display Alternatives

When the author first thought of using a PIC to generate the l.e.d. output display, his initial idea was to have a display that varied continuously from green through orange to red as the temperature varied from 5ºC down to 0ºC. This can be done by flashing each half of the l.e.d. display faster than the eye can perceive, but with varying mark/space ratios to give differing average proportions of red and green in the light output.

A PIC program to do this was written, and is supplied as **iceboxa.asm** and **iceboxa.hex**, so that readers may experiment with it if they so wish. The software is available for free download from the "Downloads" section on the *EPE* website at **www.epemag.co.uk** and pre-programmed chips are available – see *Shoptalk*

However, the author found that, especially in lighting conditions varying from

pitch dark through to full (winter) sunlight, this colour display was not easy to read and interpret at a glance. A display that requires concentrating on for several seconds to decide if it is more red than orange, for example, is probably not making a very positive contribution to road safety. It is probably also of little use to anyone who is colour blind.

He therefore reverted to using display patterns comprising a number of still and flashing red and green displays. These patterns are illustrated in Table 1. Each pattern is displayed for a temperature range of just over 1ºC (theoretically, 1·08ºC). These patterns have been found to be easily recognisable at a glance. The program to generate these displays is **icebox.asm** and **icebox.hex**.

Table 1: Display Patterns

Display	*Threshold Voltage*	*A/D Units*	*Temperature, Celsius*
Solid Green	3·98	>204	>5·4
Green – slow flash	3·38	173 - 204	4·3 - 5·4
Green – fast flash	2·77	142 - 172	3·2 - 4·3
Solid Red	2·19	112 - 141	2·2 - 3·2
Red – slow flash	1·58	81 - 140	1·1 - 2·2
Red – fast flash	1·00	51 - 80	0·0 - 1·1
Red/Green alternate	<1·00	<51	<0·0

Software

The beauty, and purpose, of using a PIC is that it is very easy to change the displays to suit individual preferences simply by changing and reloading the software. Program **icebox.asm** has been written to be easily modifiable by readers, and the PIC12F675 can be programmed with *TK3* software/hardware. Constants defining the flash rates (FASTRATE and SLOWRATE), the main loop execution frequency (SPEED) and the threshold ranges are placed at the beginning of the program, so that minor tweaking can be done just by changing these constants and reassembling.

Program **icebox.asm** is not very long nor difficult to understand. After initialising the PIC registers, it enters the main loop which is basically timed using Timer0, and secondarily timed using software counters. With the internal clock running at 4MHz, and the Timer0 parameters as given, the Timer0 clock "ticks" at 61Hz.

The main loop executes every SPEED clock ticks, so with the default value of SPEED = 18, this is about 3·4Hz. With FASTRATE set to 1, this is also the fast l.e.d. flash rate.

Every ADRATE (default 4) times round the main loop, a new A/D value is obtained. The raw A/D output is divided by four, discarding the least significant two bits, and the program then compares this A/D units value with a set of threshold values.

Depending on the value, it will call one of a set of routines which recalculate the flash parameters. On subsequent timer ticks these parameters are used by the main loop code starting at label FLASH to create the different l.e.d. display patterns, until the next A/D value is obtained.

The watchdog timer is enabled in the configuration. The PIC program can be restarted at any time, probably without the user ever noticing. It is hoped that this may make the circuit resilient to at least some possible faults, perhaps caused by voltage spikes on the supply or similar, but this is very hard to test.

Incidentally, the lack of a simple multiple relationship between the settings of the constants SLOWRATE and ADRATE leads to an unequal mark/space ratio in the slow flash displays. This effect was discovered by accident when the author mistyped a value during testing. But having seen it, he liked it, and has kept it ever since!

Exclusive OR

One point which may benefit from a brief explanation is the use of the Exclusive OR (XOR) instruction **xorwf**. The truth table for XOR is shown in Table 2. Put into words, when two bits (or a byte of eight bits) are XORed together, the result is a '1' if the corresponding bits are different otherwise the result is a '0'.

Table 2: - XOR Truth Table

Input 1	*Input 0*	*Output*
1	0	1
1	1	0
0	1	1
0	0	0

One consequence of this logic is that if the two bytes to be XORed together are regarded as a "target" value and a "mask" value, with the result to be stored back into the target and the mask left unchanged, then in bit positions where the mask contains a '1' value the target bits at those positions will have their values reversed. That is, if they were initially '1', after the XOR they will have zero at these positions, and if they were '0' they will now be '1'.

Bits at positions where the mask contains zero will be unchanged. Repeating the XOR operation with the same mask, and with the target containing the output of the first XOR, recovers the starting value of the target! The best way to convince yourself of this is to try it with a pencil and paper and some test values.

In our case, the "target" is the GPIO register. The "mask" is TOGVAL, which has '1' bits set corresponding to the l.e.d. or l.e.d.s that need to be flashed. The main loop then repeatedly XORs TOGVAL (having loaded it into W) with GPIO, which toggles it between two different states to obtain the flashing effect.

As a small digression, suppose that in a program you need to exchange the values in two bytes, A and B. In other words, you want location A to contain the value presently in B, and B the value at present in A. The naive way would be to copy A to a third location C, then copy B to A, then copy C to B.

But there's an old programmers' trick for doing it without using a third location. If you do the sequence A XOR B, B XOR A, A XOR B, then you will find that B contains the original value of A, and A contains B. Try it and see!

OSCCAL

Normal manufacturing process variation means that the internal oscillator of the PIC12F675 may not run at precisely its nominal frequency of 4MHz. When shipped, each part contains a calibration value in the highest word of program memory (h'3FF') in the form of a **retlw** instruction. A **CALL 0x3FF** instruction returns a value in W which can then be loaded into the OSCCAL register to "trim" the oscillator to precisely 4MHz.

A feature of the PIC12F675 is that it is necessary to bulk erase the program memory before it can be reprogrammed. This bulk erase also erases the calibration value. So before reprogramming a PIC12F675 a good PIC programmer will first read the calibration value, then erase and reprogram the chip, and finally restore the calibration value back to location h'3FF'.

Unfortunately, it would seem that there are a number of PIC programmers out there that are not capable of performing this juggling act correctly, and so the calibration value can easily get lost. And once lost it is gone for good – unless somebody has a note of it on a piece of paper somewhere, so that it can be restored manually, or a complicated recalibration procedure needing specialist kit is performed.

Unfortunately again, there is no simple way to test whether location h'3FF' contains a "good" instruction before it is used. If it does not, doing a **CALL 0x3FF** instruction is likely to have fatal consequences for the program.

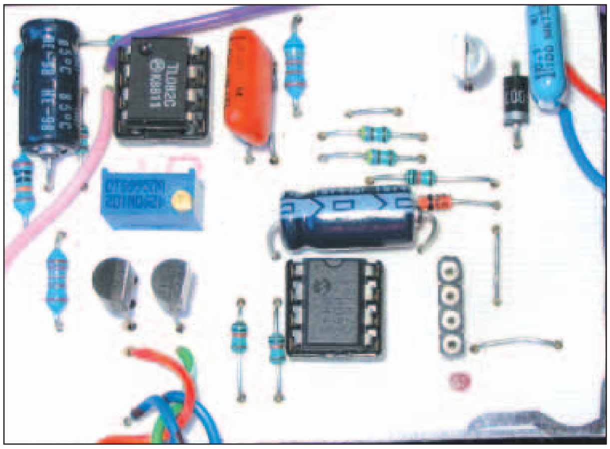
The Frost Box application does not need a precise oscillator frequency, so by default the software does not program OSCCAL, to avoid the possible nasty consequences of attempting it with an incorrectly programmed PIC. However, if you know that your particular PIC12F675 has a good value in its calibration word, you can remove the semicolon (comment symbol) from the line **; #define DO_OSCCAL** and reassemble. This will enable code to program OSCCAL.

Microchip seem to have realised that this particular piece of design is perhaps slightly less than optimal, and more recent 12F devices like the 12F683 put the calibration value where it is less likely to get overwritten – but also where it is harder to use.

Components

It is probably possible to substitute certain components. The author prototyped the circuit using a MAX492 op.amp for IC1, because its rail-to-rail output swing potentially gives a greater resolution, but reverted to the cheaper TL082 when it was decided that this extra accuracy was unnecessary.

As it is used essentially as a d.c. amplifier, the slew rate properties etc of the op.amp should be unimportant. It should be possible to use any general purpose *npn* transistors for TR1 and TR2. But resist any temptation to substitute a cheaper single-turn preset potentiometer for VR1 in place of the multiturn component specified. The calibration adjustment is quite critical, and could prove frustratingly dif-



Components mounted on the completed circuit board

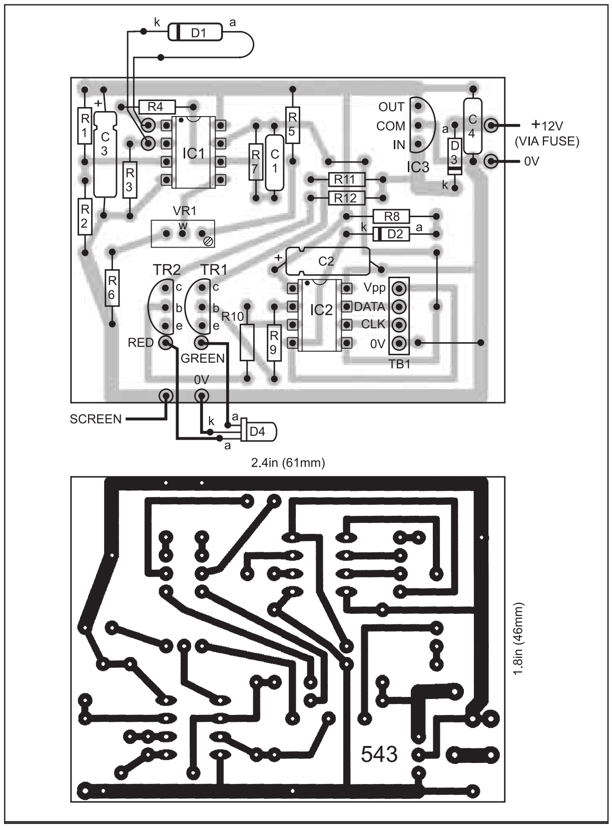


Fig.2. Frost Box Mk2 printed circuit board component layout, wiring and full-size copperfoil master pattern

ficult to achieve on a single-turn pot.

The author has successfully tried a PIC12F683 in place of the PIC12F675. It is pin compatible, but a few amendments to the software are necessary. However, it is more expensive than the PIC12F675 (unless you happen to have one already); seems harder to obtain (at least in the UK); offers no additional useful features for this application; at the time of writing is not supported by *TK3* (V3.00).

Regulation Chat

Discussions have appeared on the *EPE Chat Zone* in which it has been suggested that the 78L05 regulator used for IC3 may not be totally proof against the voltage spikes and other hazards in the general automotive electrical environment. Notwithstanding, the author has used the original circuit, containing a 78L05, continuously in his car for five years without any apparent problem.

It must be stated that the author's circuit is installed in the car boot, close to the battery (which, unusually, is also located in the boot), and physically and electrically far away from ignition components and most other electrical devices under the bonnet.

If readers do experience problems with spikes from ignition circuits etc, the LM2940 regulator might be a more robust substitute for IC3, although this has not been tried. It is probably a sensible and inexpensive precaution to thread a couple of ferrite beads onto the power supply leads. It would also be sensible to disconnect the circuit before doing anything unusual to the car's electrics, e.g. heavy duty jump starting.

Construction

Printed circuit board (p.c.b.) component and track layout details are shown in Fig.2. This board is available from the *EPE Service*, code 543.

Construction of the circuit is straightforward. Begin with the small components, resistors and wire links, then the larger components. If the wire links are made to loop away from the board slightly, such that a meter clip probe can be hooked onto them, they may serve as useful test points later.

Use sockets for IC1 and IC2. The l.e.d. may either be mounted in the circuit box, or remotely using a cable, depending on individual installation requirements.

Do thoroughly check the board for assembly and soldering errors before connecting it to a power supply.

Sensor

The 1N4148 diode temperature sensor with its fragile glass encapsulation needs some protection if it is to survive for long mounted underneath a car. The author is unable to suggest any improvements to Steve Dellow's original ideas for encapsulating the sensor, but the following section contains his particular angle on how best to do it.

Carefully bend one of the leads of the diode through 180º so that it lies back along the body of the diode, and both leads are now parallel and point in the same direction, see Fig.2.

Obtain some kind of small metal tube, closed at one end, a centimetre or so long into which the diode will fit – an automotive electrical bullet connector is suitable. The diode should be a reasonably snug fit

COMPONENTS

Approx. Cost Guidance Only **£17**

Resistors

R1, R2	100k (2 off)	
R3, R4	1k (2 off)	
R5	6k8	
R6	12k	
R7	220k	
R8	10k	
R9, R10	4k7 (2 off)	
R11, R12	470Ω (2 off)	

All 0.25W 5% carbon film or better

See SHOP TALK page

Potentiometer

VR1 — 1k multiturn cermet preset

Capacitors

C1, C4	100n polyester (2 off)
C2, C3	47µ axial elect., 16V (2 off)

Semiconductors

D1, D2	1N4148 signal diode (2 off)
D3	1N4007 rectifier diode
D4	red/green bicolour l.e.d.
IC1	TL082 dual op.amp
IC2	PIC12F675 microcontroller pre-programmed (see text)
IC3	78L05 +5V 100mA voltage regulator
TR1, TR2	2N3904 *npn* transistor (2 off)

Miscellaneous

FS1 — in-line fuseholder and 100mA fuse

Printed circuit board, available from the *EPE PCB Service*, code 543; 8-pin d.i.l. socket (2 off); 4-way s.i.l. socket; audio twin-core screened cable, length to suit vehicle; car electrical bullet connector (see text); epoxy resin adhesive; 1mm hook-up wire; plastic case 75mm x 55mm x 55mm; vehicle grade connecting wire for power supply; heat shrink sleeving (see text) solder pins; solder etc.

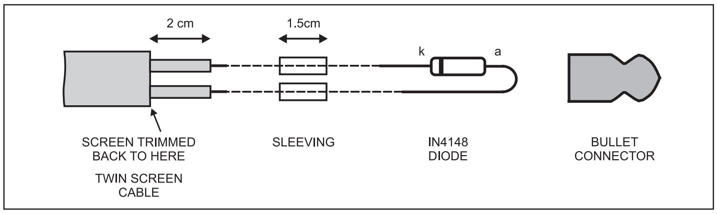
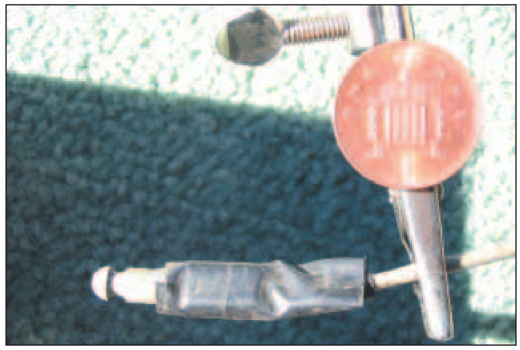


Fig.3. Suggested sensor housing for the diode frost/ice detector



Temperature sensor assembly using a car bullet connector

inside the tube, otherwise the thermal inertia of the enclosure will deaden the response time to rapid temperature changes, but the diode leads must not touch and make electrical contact with the sides of the metal tube.

One of those "helping hands" gadgets with crocodile clip arms mounted on ball joints is useful at this point. Mount the tube vertically, open end up, using one of the crocodile clips. Mix up sufficient epoxy resin adhesive to fill the tube, and poke it into the tube with a matchstick, trying to ensure that no air bubbles are left inside.

Now push the diode carefully into the glue, so that the glass part is completely covered and the leads stick out vertically upwards. Wipe away any excess glue, check with a meter that the leads are not touching the metal can, and when satisfied clamp the diode in position using the other crocodile clip arm. Put the whole assembly carefully aside until the glue has thoroughly set.

Twin-core screened cable should be used for the lead connecting the diode sensor to the circuit. Get two pieces of sleeving about 1·5cm long – heat-shrink sleeving is good if you have any, or take the copper wire out of a small length of flat house wiring cable. Strip back 2cm of the screened cable, cut back the screen to the outer insulation, and thread the sleeving onto the two inner conductor leads – see Fig.3.

Now, when the diode assembly has fully set, solder the screened cable wires to the diode leads as close as possible to the enclosing can, very carefully – you don't want to fry the diode at this stage! If you lack confidence in your soldering abilities, use a crocodile clip as a heatsink between the can and the solder point.

Trim off any excess diode leads, and pull the sleeving up over the solder joints to give them some mechanical strength. Secure the whole lot with more (wider diameter) heat-shrink sleeving, or bind it round with insulating tape. Don't cover too much of the metal can with tape, or this will impair its thermal conductivity too.

Finally, test with a meter that the diode has survived and is still functioning. If so, solder the other end of the screened lead to the circuit board, taking care to get the polarity correct, and connect the screen to the circuit ground (0V).

Testing

After assembly, inspect the board carefully for solder splashes, dry joints etc. Do not insert IC1 and IC2 yet. Before applying power, do a sanity check with a meter across the board power rails to verify that there is no short. If all is well, apply power to the input and check for 5·0V at IC1 socket pin 8 and IC2 socket pin 1.

Insert IC1, and monitor IC1b output voltage with a meter (the wire link may be a convenient test point). Unless the diode sensor is very warm, it should be possible to balance IC1b by adjusting preset VR1.

Multiturn pots are enclosed, so you can't see where the wiper is. It's therefore hard to know which way to turn the adjustment screw initially. There is no end stop on most types; instead there is a sort of clutch or ratchet arrangement which slips when the wiper has reached the end of its travel. If you listen very carefully, you can usually hear a very faint ticking noise when you turn the screw adjuster as the clutch slips.

If you have trouble with adjusting VR1, it's possible that you are slipping at the end of the wiper's travel. Listen for this tick, and/or check with a meter whether the voltage at the wiper terminal is changing. If it isn't you have probably overshot the required point, and need to go back the other way. Remember that this is a multiturn component, so several turns of the screw may be necessary to find the right point. Set the output voltage to around 2·5V.

Power down and, using normal static precautions, insert a suitably programmed PIC into socket IC2, and re-apply power. The l.e.d.s (D4) should light in some display pattern. By adjusting VR1, it should be possible to take the display through its complete range of patterns. If the display flashes red/green alternate whatever the setting of VR1, check the polarity of the diode connection.

Calibration

To calibrate the unit, first put some ice cubes in a glass or mug, and add a little water. Allow this mixture to come to equilibrium, stirring from time to time – remember that 0ºC is the temperature of *melting* ice, and that ice cubes straight from the freezer are likely be considerably colder than this. Insert the diode temperature probe into the ice-water mixture, switch on the circuit, and allow a few minutes for everything to settle down.

When it has, adjust preset VR1 so that the display has just switched into the alternating red/green display from the fast green flash display. This calibrates the circuit so that the alternating red/green display represents a temperature of 0ºC or below, and the other displays represent various temperatures up to 5ºC or so above freezing.

It is best to do this procedure with the circuit as near to its intended operating temperature as possible. This depends on where the circuit will be installed in the car. If this is the car cabin, then normal room temperature will be OK, assuming of course that your car heater is working. If (as in the author's case) it is to be installed in the unheated boot or under the bonnet, then it is better to have the circuit at the appropriate temperature, say around 5ºC, while it is calibrated.

This is because every semiconductor junction in the circuit is temperature sensitive (and every resistor too, though to a lesser extent), not just the sensor! While we are not amplifying these other junctions, it will nonetheless be found that the circuit output will vary a little when it is at different temperatures, even if the probe remains at the same temperature.

Installation

The circuit board is designed to be a snug fit inside a small plastic box 75mm × 55mm × 55mm. The author did not mount the board using screws or pillars etc. Instead a couple of pieces of that size were cut from an old Jiffy bag, and put into the bottom of the box, the idea being to provide some cushioning for the p.c.b. against the general bumps and vibration which are an inevitable part of life when travelling around in an elderly sports car.

The circuit board was then simply placed on top of these pieces. The natural springiness of the connection wires to the sensor, l.e.d. and power supply hold the p.c.b. pressed against this cushion, and should provide more shock absorption.

For good measure, the box was wrapped in several layers of "bubble wrap", before being tucked behind a convenient piece of the wiring harness. Other installation details clearly depend on individual preferences, make and type of car etc, so only general advice is given.

The sensor is intended to be put somewhere fairly near the road surface, so that as nearly as possible it measures the road temperature. It should not be exposed to too much wind, to avoid wind chill effects, particularly when wet, and ideally somewhere that affords some protection from road debris thrown up by the wheels.

Stay well clear of the exhaust system components, for obvious reasons. Behind a front bumper or similar location is probably quite good. Take care that the cable is secured clear of all moving parts, and avoids any fluid leaks such as battery acid, oil etc.

The power supply should be taken from a suitable ignition switched point. A 100mA in-line fuse should be used. Unless a top-of-the-range car with all options fitted is used, there are likely to be a number of connecters on the wiring harness which have nothing plugged into them. Experiment with a test meter to find which pins are live at the right times. The circuit draws less than 20mA maximum current, and is unlikely to overload any automotive circuit fuse which may be protecting the circuit used. □

News . . .

A roundup of the latest Everyday News from the world of electronics

ENTER THE I-MODE

Barry Fox reports on how Japan's i-mode is coming to the UK, riding in on the back of the dismal failure of WAP

BT Cellnet was the first cellphone network to launch a WAP – Wireless Application Protocol – service, in January 2000. "Suddenly the Internet just isn't PC any more" promised Cellnet roadside hoardings selling the idea of Internet on the move with a WAP cellphone.

WAP was soon being tagged as WAP Cr*p, as people with WAP phones found they did not have access to the Internet. All they got was snailspace access to a few selected sites which had been completely re-jigged to strip out graphics and make text legible on a tiny screen.

WAP phones were difficult to get working and Cellnet's helplines were hopelessly out of their depth. The consumer press warned customers that if they wanted to use WAP they should insist on the phone being set up to work before leaving the shop.

Japan's i-Mode

Meanwhile in Japan, cellphone network BTT DoCoMo was launching a much better service called i-mode. It still gave only limited access to the Internet but the sites were much easier to find and use.

There are now over 50 million i-mode users in 22 countries round the world and O2 (which morphed out of BT Cellnet) has thrown in the towel and launched the first UK i-mode service. In a significant move O2 is using the failure of GSM/GPRS WAP to promote i-mode on GSM/GPRS. New phones will be needed, and O2 is launching with four from NEC and Samsung.

Says Grahame Riddell, Head of i-mode Marketing for O2: "Many customers are dissatisfied with today's data services ... they are frustrated with mobile Internet – it's a disappointing experience ... they don't know how much WAP costs – no-one has a clue how much mobile services cost – it's all over the place – seven out of ten people who buy i-mode handsets use the service, compared to just three who use the available WAP services on their handset."

Pricing and Promotion

O2's i-mode pricing is based on £3 per 1MB of data received, in addition to whatever monthly subscription sites charge – access could be free for banking services or £3 a month for news sites.

In promoting i-mode by disparaging WAP, O2 is again running the risk of disappointing consumers:

"WAP is slow and WAP content has to be created" admits Riddell. "But i-mode takes Internet content. We are offering Internet at the touch of a button"

In late September O2 was planning to launch i-mode on October 1st and start "the biggest ever advertising campaign since the launch of the company", on October 10th. High posters, similar to those which over-promised on WAP five years ago, will now promise "Internet at the touch of a button", "I can take you anywhere" and "I am faster than WAP", with the "I" represented as the "i" of i-mode.

At launch the i-mode service will have access to only 100 sites, whereas Japan has 4000. There will be more sites coming on stream, Riddell assures. It costs around £8,000 to £10,000 and takes two to three months work to convert an existing Internet site for i-mode access.

Reconciling Claims

How does O2 reconcile the "Internet at the touch of a button" and "I take you anywhere" promises with the reality of access to a hundred sites through the O2 portal? Surely this could land O2 with complaints to the Advertising Standards Authority?

"We are not claiming to offer every Internet site – we are not-over-promising", Riddell says.

Riddell confirms that the posters were devised by O2's advertising agency and assure that before the campaign launch, they were put to the advertising authorities for approval before use.

Upgrading Mobiles

Good news for people who resent having to buy new mobile phones to get new features; and it comes from an unlikely source, phone giant Sony Ericsson (US 2004/0014531). Sony admits it is often impossible to use or fully exploit a new phone accessory, such as a camera gadget, with an existing phone. The menu of options frozen into the phone at the time of manufacture does not support new cleverness, like emailing pictures.

Sony's solution is to make the phone's menus flexible. When a new accessory is connected to the phone, either by cable, infra-red or Bluetooth radio, the phone and accessory exchange electronic handshakes to check whether the accessory is licensed for use with the phone. If it is, the accessory squirts new menu software into the phone. The old phone then works perfectly with the new accessory.

Barry Fox

Two-Pole Tester

A new Fluke electrical tester offers a low-cost solution (recommended price £20) to professional electricians and maintenance personnel for rapid a.c./d.c. measurement and continuity testing. Like the Fluke T100 series of 2-pole testers which it complements, the T50 is designed with user safety as a primary consideration.

The rugged T50 measures a.c./d.c. voltages from 12V up to 690V and has Category III 600V safety rating. It features an easy to read 10-l.e.d. display which indicates the most commonly-encountered voltages even with batteries. Optical and acoustic indicators provide continuity testing. The tester also indicates polarity and features a single-pole test for phase detection.

For more information contact Fluke (U.K.) Ltd., Dept EPE, 52 Hurricane Way, Norwich, Norfolk NR6 6JB. Tel: 0207 942 0700. Fax: 0207 942 0701. Email: industrial@uk.fluke.nl. Web: **www.fluke.co.uk**.

MORE RAPID LITERATURE

In *News* of the previous issue, November, we mentioned that Rapid Electronics had sent us literature, particularly highlighting their Winter 2005 *Focus* publication. We have since received more, including their Design & Technology and Science catalogues for 2005/6. Both are for schools and worthy of obtaining by teachers involved in such subjects.

The topics covered include not only those which are electronics orientated, but also pure hardware, such as magnifiers, microscopes, and even model dinosaurs that walk! Overall the categories are Physics, Chemistry, Biology, General Science and tools – indeed, all those things that will delight a child's imagination and encourage him or her to take an interest in the fascinating world around us.

To find out more contact Rapid Electronics Ltd., Severalls Lane, Colchester, Essex CO4 5JS. Tel: 01202 751166. Fax: 01206 751188. Email: education@rapidelec.co.uk. Web: **www.rapideducation.co.uk**.

SCHMARTBOARD/EZ

We have previously highlighted the benefits of Schmartboard through these pages and are pleased to do so again after receiving another press release from the company.

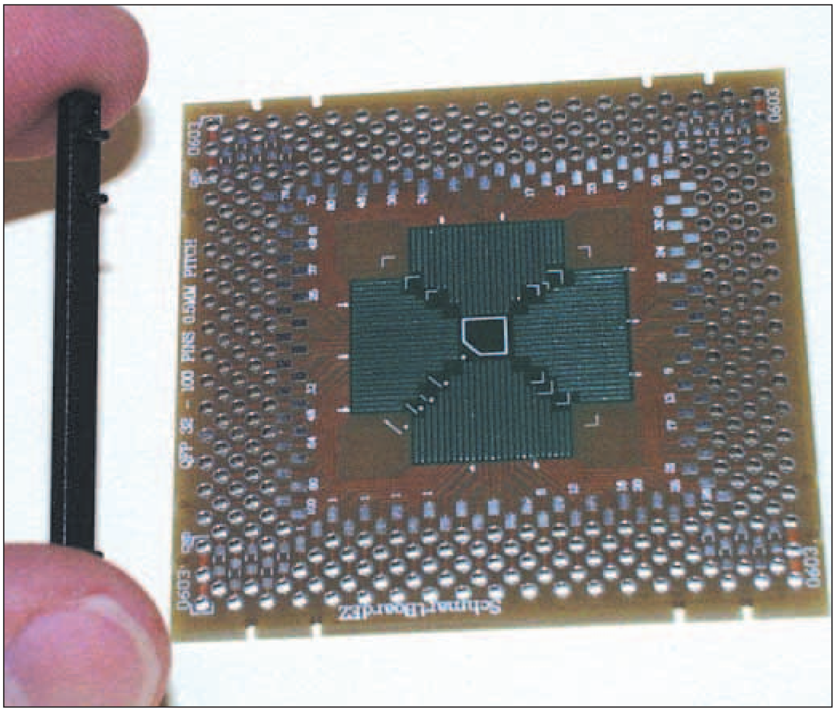
This time the release talks of the new SchmartBoard/ez, in particular emphasising the product's suitedness for people who find themselves impeded by the their ability to hand-solder surface mount components and by soldering in small confined areas.

SchmartBoard/ez's patent pending technology aims to solve these issues. Unlike all other circuit boards, the solder mask is higher than the pads, not lower. This creates canals, the walls of which are made by the solder mask, and the floor of the canal is the pad surface. The legs of an i.c. fit into this canal, thus allowing easy hand-placement of the chip legs onto the pads.

A fine tipped iron is then used, but no additional solder is needed. The existing solder is simply heated while pushing the iron from the lateral end of the canal.

The press release also included a catalogue of the wide variety of forms in which the product is available.

For more information contact Schmartboard Inc., Dept. EPE, 44081 Old Warm Springs Boulevard, Fremont, CA 94538, USA. Tel: 510 659 1549. Fax: 510 659 1644. Web: **www.schmartboard.com**.



GPS Navigator

Following on from the publication of Mike Hibbett's *Speed Camera Watch Mk2* in Nov '05, it's interesting to be advised that a new commercial Safety Camera and Navigation device has been released by GPX Technologies. They say that their GPX Navigator is the ultimate satellite powered driving aid, helping to control your speed, aid navigation and improving driving safety.

The GPX Navigator combines safety camera and accident blackspot alerts, directional navigation and digital trip computer functionality. David Baxter, Managing Director of GPX Technologies, says that "the marketplace for GPS-based safety camera locators is dominated by products that typically cost in the region of £400". The new device has a suggested retail price of £199.95, including VAT.

It offers early warning of a range of fixed safety cameras, including GATSO, Truvelo, Watchman and SPECS. Alerts are provided audibly and, via a high contrast or matrix l.e.d. display, in the form of easy-to-read messages.

The navigator's comprehensive safety camera and accident blackspot database is rigorously maintained and provides the most accurate information possible. To keep your database up-to-date, simply connect the device to your PC and update via the internet. Updating is via a subscription-based system, accessible free for six months, thereafter at £50 per year, including VAT.

For more information contact GPX Technologies Ltd., The Inox Building, Caldwellside, Lanark, ML11 7SR. Tel: 0870 350 2305. Fax: 0870 350 2307. Email: enquiries@gpxtechnologies.com. Web: **www.gpxtechnologies.com**.

Love Cool Gadgets?

That's the question posed by Maplin in their latest press release, including the love of electronic components as well. They go on to say that these subjects, and a whole lot more, are covered in their brand new 2005/06 catalogue.

Furthermore, the new cat has over 18,000 new lines, including audio, video, electronic, computer products, components and accessories. It is designed to provide you with a clear guide to Maplin's massive and ever-growing range of specialist electronic products and contains a wealth of information allowing you to make informed purchases.

The catalogue costs £3.99 and there are £200 worth of special offer vouchers and discounts inside. There is no delivery charge. To get your copy, phone 0870 429 6000, or call in to any one of Maplin's many nationwide stores.

HumidiProbe

Pico Technology have added another logger to their ever-increasing range of dataloggers. This one's the HumidiProbe, a combined datalogger and converter that plugs into the USB port to give instant measurements of temperature and humidity,

HumidiProbe can measure temperatures over the range 0°C to +70°C, with an accuracy of ±0·5°C, with a resolution of 0·01°C, and a response time of five to 30 seconds. It measures relative humidity over the range 0% to 100% with an accuracy of ±2%, a resolution of 0·03% and a response time of four seconds.

The logger is compatible with USB 1.1 and USB 2.0 ports, and port selection is automatic, taking its power from the port. It is supplied with easy-to-use Picolog software, which is a powerful and flexible program used to collect, display and analyse data. Measurements can be viewed in graph, spreadsheet and text formats and saved to file. Software alarms can be configured to give a warning when values exceed a specified range. Up to four units can be plugged in simultaneously.

HumidiProbe costs £149 plus VAT. For more information contact Pico Technology Ltd., The Mill House, Cambridge Street, St Neots, Cambs PE19 1QB. Tel: 01480 396395. Fax: 01480 396296. Email: publicrelations@picotech.com. Web: **www.picotech.com**.

TECHNO-TALK MARK NELSON

BIG SWITCH, LITTLE SWITCH

The coming closedown of analogue TV and switch to digital is making the headlines. But a far bigger change is coming that may make this "news" entirely irrelevant, as Mark Nelson reports

LATELY the UK government confirmed its intention to switch off analogue TV signals by 2012. The Border Television region will be first to make the switch, with other regions following successively until 2012. It's a move that will fascinate many, perplex others and annoy the hell out of those who thought buying a Freeview box was the ultimate in up-to-date chic. It's big news right now but it's not the real news. It's a switch but not the big switch.

The big switch is the Negroponte Switch, described in this column back in July 2003. If your recall doesn't stretch that far back, here's an instant rewind. A while back the one-time technology guru Nicholas Negroponte claimed that wires and wireless would change place. Tasks traditionally performed by radio waves (such as broadcast TV and radio) would turn increasingly to cable, he argued, whilst a wirefree future beckoned for communication functions previously handled exclusively by wired means.

Modestly he called this turnabout the "Negroponte Switch" and to a degree his prediction has already come true with the success of cable TV and broadband in the home. But even he would have been hard-pressed to forecast the next step in this switcharound. Forget digital TV over the airwaves, forget conventional cable TV – the future is IPTV delivered down standard telephone lines.

TV's New Image?

IP is everywhere these days. You'll know IP or Internet Protocol as the data format language of the Internet, but it's used across many telephone networks to carry speech as well. Now it's being touted for TV too, the darling of technology companies looking for new opportunities in a flagging marketplace.

IPTV is arguably one of the hottest new technologies right now and "the next big technology step for many of our customers worldwide, a step away from pure telecommunications toward new sources of revenue," as German industry giant Siemens stated at the Broadband World Forum in October. If this is refreshing news for industry, it's also highly welcome to consumers who can look forward to a broader choice of video and audio channels in the home, delivered by phone line.

IPTV uses the same DSL (digital subscriber line) high-speed connection that phone companies like BT use to deliver broadband Internet access over standard copper telephone lines. It needs some pretty nifty data processing too, for which Microsoft and other companies have developed a range of server products and set-top boxes.

BT is in fact at the forefront and announced recently that its BT Entertainment division would launch its own IPTV offering next summer, initially offering video-on-demand, but not live BBC and ITV streams. Hardly revolutionary, you might think, but an exclusive report in *The Business* gives a clearer – and entirely credible – vision of what this could mean.

Transforming Habits

Technology Editor Tony Glover revealed how British viewers could soon be able to have their own individual channel as one of a range of interactive TV services planned by BT. Households that signed up would no longer be tied to the fixed packages offered by the likes of NTL and Sky Channel. Instead they could pick and mix from a much broader range of mass and niche market TV, literally on demand and at whim.

Even better, the two-way nature of broadband would mean they could create their own channel containing content such as home movies and photo collections. "Friends and relatives will be able to access the channel on their TV sets via the remote in the same way they would access a regular TV channel," stated Glover, quoting a senior source inside BT who argued Internet TV applications like these would transform the nation's viewing habits.

The technology that makes this feasible is MyOwnTV, from French electronics manufacturer Alcatel. The company's website describes MyOwnTV as a user-friendly way to upload multimedia content such as movies and photos and then share it with a specified group of people (the local community or a particular affinity group). As well as allowing friends and families to share personal "stuff", this service could let clubs, societies, football teams or local communities to create their own TV channels.

Personal Services

"Research shows that people want to see themselves on TV," declared Alcatel's Alan Mottram at the Broadband World Forum. "You will be able to publish and share information through the TV, post your home videos to friends and family through the same program guide that controls your TV," he said. Be that as it may, it's clear that viewers fed up with the "200 channels and nothing on!" syndrome will welcome the chance to put their own stamp on truly personal choice of entertainment. It's equally clear that despite the huge investment needed to fulfil this wish, operators are keen to make it happen.

Internet Telephony and other budget phone offerings are shaving the margins off traditional telephony, whilst some pundits predict that phone calls will soon come gratis with any broadband Internet subscription, in the same way that email is already a free giveaway. IPTV is an ideal way for incumbent telephone operators to hit back by offering value-added services that OneTel and TalkTalk cannot provide.

Nor is BT by any means the only phone company seeking to snatch this new revenue stream; word has it that Cable & Wireless-owned internet service provider Bulldog is expected to compete keenly for interactive TV service provision.

Technical Challenge

If you are thinking all this sounds too good to be true, you are right to be sceptical. No-one denies the scale of the technical challenge involved to achieve jitter-free pictures and audio that come close to broadcast TV standards, nor the colossal financial investment required to make this a reality. Then there will be the inevitable incompatibility of proprietary standards and protocol conversion problems.

That said, broadband DSL has come a very long way in the last couple of years and there's no reason to believe the technology has reached finality. The biggest bugbear is the inconsistency of the phone companies' copper telephone lines, which could easily make service feasible on one side of the street and not on the other. Line length will have a profound effect on quality of service and tests that work fine in a laboratory environment may come a cropper in the real world where cables pass through damp manhole chambers and end up on exposed wall boxes with missing lids.

Look Before You Leap

Consultant Thomas Hazlett observes that across the Atlantic the Negroponte Switch is already being thrown by millions of consumers who are abandoning traditional TV delivered over the air for nothing in favour of fee-based services and the same could well happen here.

One thing's certain: IPTV delivered down phone lines is a classic "disruptive" technology and will place a big question mark over digital TV over the airwaves and from satellites. If you were thinking of splashing out on a new digital-ready TV set, you might reconsider whether now is the right time to make that investment. That brand-new set might be obsolete before you buy it!

PIC N' MIX

MIKE HIBBETT

Our periodic column for your PIC programming enlightenment

How to implement a PIC Bootloader

WRITING software for microcontroller based projects, especially PICs, typically consists of the following sequence of events:

A: Write software
B: Burn program into processor memory
C: Power up the processor, observe how the code runs
D: If not what you want, go to A

This cycle is commonly referred to as the "crash and burn" development process, because you repeat it until the software stops crashing! Although very primitive this technique is still in use today in professional environments where simple microcontroller based-systems are being developed.

Development Key Issue

A key issue to reducing development time, and engineer stress, is reducing the amount of time it takes to reprogram your processor. If you are really unlucky you may have to remove i.c.s and wait several minutes while a device is reprogrammed. Where there are lots of wires, connections can often break, creating confusion as to the source of the latest problem. We can hear a thousand voices say "been there, done that"!

In-circuit serial programmers can help but often require special programming hardware. And what if you want your end users to be able to easily load new versions of the software?

There is a technique used by embedded engineers to get round this, called "bootloaders". These are small pieces of software built into the application code that can be called upon to use existing application hardware, such as a serial port or even a CD drive in the case of DVD players, and use this interface to receive a new version of the application software. The bootloader will then re-write the application software, sometimes even overwriting itself!

Bootloader Requirements

There are a few requirements that must be met before a bootloader can even be considered. First, the hardware must have memory that can be written to directly under software control. Secondly, you must have all the voltages and control signals required for programming available on your board. Some memories, such as EPROM, may run at 5V but require 12V for programming.

So let's take a look at our favourite microcontroller, the PIC. The "C" variants, such as 16C, 17C, 18C have one-time programmable memories, so they are out. The smaller flash variants, such as 16F628, 16F84, do not have the instructions to be able to write to the flash. The more modern 18F families, however, implement the table write instruction, **TBLWT**, which is just what we are looking for.

The final constraint that can sometimes remove the ability to implement a bootloader is how the memory is erased. Due to the way in which flash memory is implementing you generally cannot erase a single byte; you must erase a larger block. If that block size is too large, the bootloader may take up too much space. A quick read of an 18F datasheet reveals that the minimum erase size is 64 bytes, and that's fine for our use.

For the purposes of this article we will use the PIC18F2420. It is small, inexpensive but has a lot of I/O and useful peripherals. To simplify the hardware requirements, we will use "bit bashed" RS232 communications, using two I/O pins. This way the real UART on the microcontroller is free for other uses.

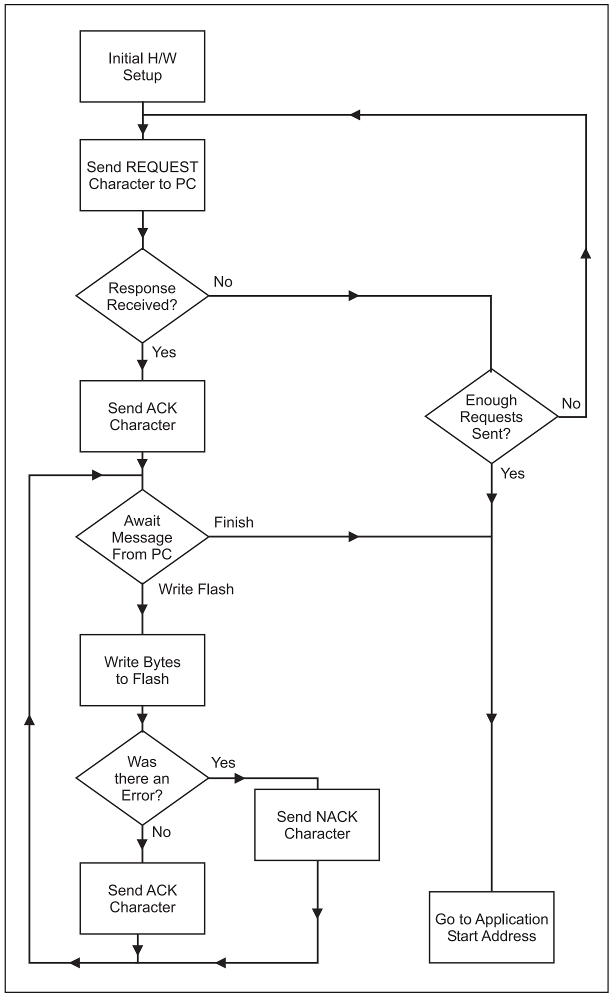


Fig.1. Flow Chart for the Bootloader

Bootloader Functions

So now to what the bootloader is going to do. We want a simple PC-based application that can read Intel hex format code files, and write them to the application hardware through the serial port. We want some feedback on the PC application that the download process has succeeded or not – after all, the application circuit may not have any user display. We also want a simple to use application environment that can make writing software with a bootloader straightforward. And to make it accessible to as wide an audience as possible, the programming language will be assembler.

This makes for an interesting problem: We must write two pieces of software, one to run on the PIC, and one to run on the PC, which must implement the same algorithm exactly, otherwise the whole system will never work. So we need a clear definition of the design, and the memory organization within the PIC.

The flowchart in Fig.1. shows how the bootloader will work. It's straightforward enough, but some points are well worth mentioning.

The initial hardware setup is entered as soon as the processor starts running. It will perform the minimum hardware setup necessary for the bootloader to operate. Then a single character is transmitted to the PC, and if the PC is connected it will send a single character response. This is repeated a few times, and if no response is received, we jump to the application code.

If we did receive a response from the PC, we send an acknowledgement character and

then go into a loop awaiting commands from the PC. Only two commands are supported; write data to flash, or finish. The write command supplies an address and a string of bytes to program; multiple write commands will be issued by the PC until all the application code has been transferred.

As each block is received the bootloader will erase the block of memory before the write. If an error occurred, such as data bytes being corrupted, the PIC will send an error message back to the PC, and the PC will retransmit the data.

What choice of RS232 Baud rate to use? As the bootloader is in complete control of the hardware we have no interrupts coming in, therefore we can run as fast as we like. A Baud rate of 115200 has been chosen, since this is the maximum speed available to the PC and has proven reliable in tests.

PIC Memory Organisation

Now let's look at the organization of the PIC's memory, and how we will partition the memory to support the bootloader and the application code. This is actually the hardest part of the design, since we want to be flexible enough to support major changes in the application code without having to re-write the bootloader or the PC application. Fig.2 shows how the PIC's flash memory has been partitioned.

To simplify application software design we will place the bootloader code at the bottom of memory, below address 0x0600. There is a complication with this – there are three critical locations in the PIC 18F processor that can never change; the Fast Interrupt Address at 0x0008 and the Slow Interrupt Address at 0x0018. The bootloader solves this problem by placing branch instructions in these locations to fixed positions in the application code space. You don't have to worry too much about this detail; the source files supplied will handle this for you.

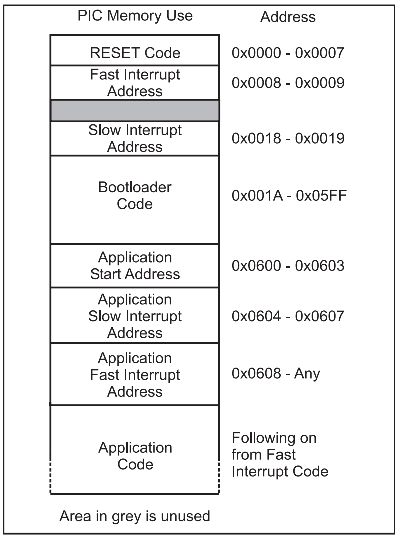


Fig.2. How PIC's memory is partitioned

The source files located in the *EPE* download area provide a 'framework' for application development. You can keep a copy of these files and use them as a template for new projects.

There are several areas where you might want to make changes. The clock speed that the processor will be running at needs to be defined in **blconst.inc**; examples are provided. The pins used by the bootloader are also defined here. You will also want to check the file **config.inc** which sets up the processor configuration registers.

Files Supplied

The files that are supplied are as follows:

main.asm: The main program source file that defines the layout of memory and the order of program execution. This file should not need changing.

bootload.inc: The source code for the bootloader. This file should not need changing.

blconst.inc: Constants that define the speed at which the PIC is running, the pins used for comms and other constants. You may change some of the constants to match your hardware setup.

interrupts.inc: Code that is placed in here will start at the application's fast interrupt address. If you are not using interrupts, you do not need to place anything in here.

config.inc: The configuration registers in the PIC18F family are quite complicated, so a single source file has been dedicated to define them. You can change these to suit your own hardware requirements.

app.inc: This is where your application code will go. The application startup code, normally called after reset, must go here and be called "main". You may include other application source files in here.

build.bat: A batch file to invoke the assembler to produce the program's hex file.

PC Software

The PC application is supplied as an **.exe** and in source code, although you should never need to change it. The PC application is a command shell utility. To run it, open a Command Prompt on your PC, change to the directory where the program is installed and type **bload**. The program will give instructions on how to use it.

bload.exe implements one special trick. Although it reads in the entire application hex file, it will not download code that is below locations 0x0600. The bootloader is in this address space, and if we tried to write there the program would crash. This is the reason for all the carefully crafted memory remapping, which makes sure that your application code can always be started by the bootloader. If you make a change to the bootloader, you must use a standard PIC programmer to download the code .

PIC Programming

Before using your code with the bootloader, you first use a normal PIC programmer to program the software into your device. Once programmed, future software updates, and even new programs, can be downloaded with just an RS232 interface.

To simplify the hardware design you can just place a 4-pin header on your board with additional +VE and ground pins so an external RS232 interface using a MAX232 chip can be built up onto a self-contained p.c.b. Or you can build the RS232 interface onto your board. As the bootloader is only used during power up, the application is free to use the port itself.

To use, run **bload.exe** and specify the COM port and file you wish to download, e.g.:

bload 1 c:\myfiles\main.hex

Once the program is running you should connect the hardware and switch it on. It will automatically sync with the **bload** program and download the application code.

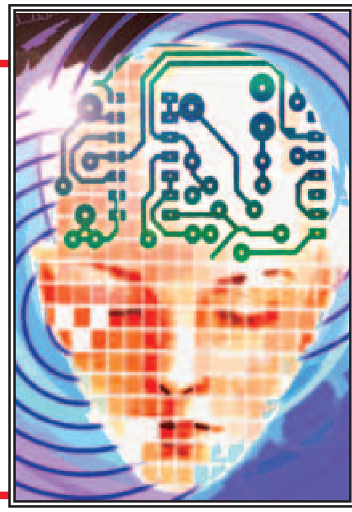
Other Methods

This is just one of many ways in which a bootloader could be implemented. For example, entry into bootloader mode could be signalled by the state of an input pin, wired to a 3-pin header on your board. The choice is up to you. The technique shown here is probably the most complex, so modifying it to suit your use will hopefully be easier, not harder!

If you would like to see an example of this bootloader in use, check out the *Speed Camera Watch Mk2* (Nov '05) project files on the downloads page of the *EPE* website, access via **www.epemag.co.uk**. The files associated with this discussion are also accessible through this site.

EPE Tutorial Series

TEACH-IN 2006



Part Two – Circuit Diagrams, Series and Parallel Circuits, Basic Measurements – The Multimeter, Kirchhoff's Laws, Power And Energy, Circuit Construction Techniques

MIKE TOOLEY BA

IN our *Teach-In 2006* series, we provide a broad-based introduction to electronics for the complete newcomer. The series also provides the more experienced reader with an opportunity to "brush up" on topics with which he or she may be less familiar. This month we get to grips with circuit diagrams, series/parallel circuits, and Kirchhoff's Laws, before taking a look at basic measurements using a multimeter and some commonly used circuit construction techniques.

LAST month we introduced this new *Teach-In 2006* series and outlined some basic information and practical investigations to get you started. This month we take our first look at circuit diagrams and circuit symbols. We also tackle basic measurements using the multimeter and explain commonly used construction techiques.

Circuit Diagrams

Before you can make sense of some of the components and circuits that you will meet later in the *Teach-In* series, it's important to be able to read and understand simple electronic circuit diagrams. Circuit diagrams use standard symbols and conventions to represent the components and wiring used in an electronic circuit.

Visually, they bear very little relationship to the physical layout of a circuit but, instead, they provide us with a "theoretical" view of the circuit. In this section we show you how to find your way round simple circuit diagrams.

To be able to understand a circuit diagram you first need to be familiar with the symbols that are used to represent the components and devices. A selection of some of the most commonly used symbols are shown in Fig.2.1. It's important to note that there are a few (thankfully quite small) differences between the symbols used in circuit diagrams of American and European origin.

As a general rule, the input to a circuit should be shown on the left of a circuit diagram and the output shown on the right. The supply (usually the most positive voltage) is normally shown at the top of the diagram and the common, 0V, or ground connection is normally shown at the bottom.

This rule is not always obeyed, particularly for complex diagrams where many signals and supply voltages may be present. Note also that, in order to simplify a circuit diagram (and avoid having too

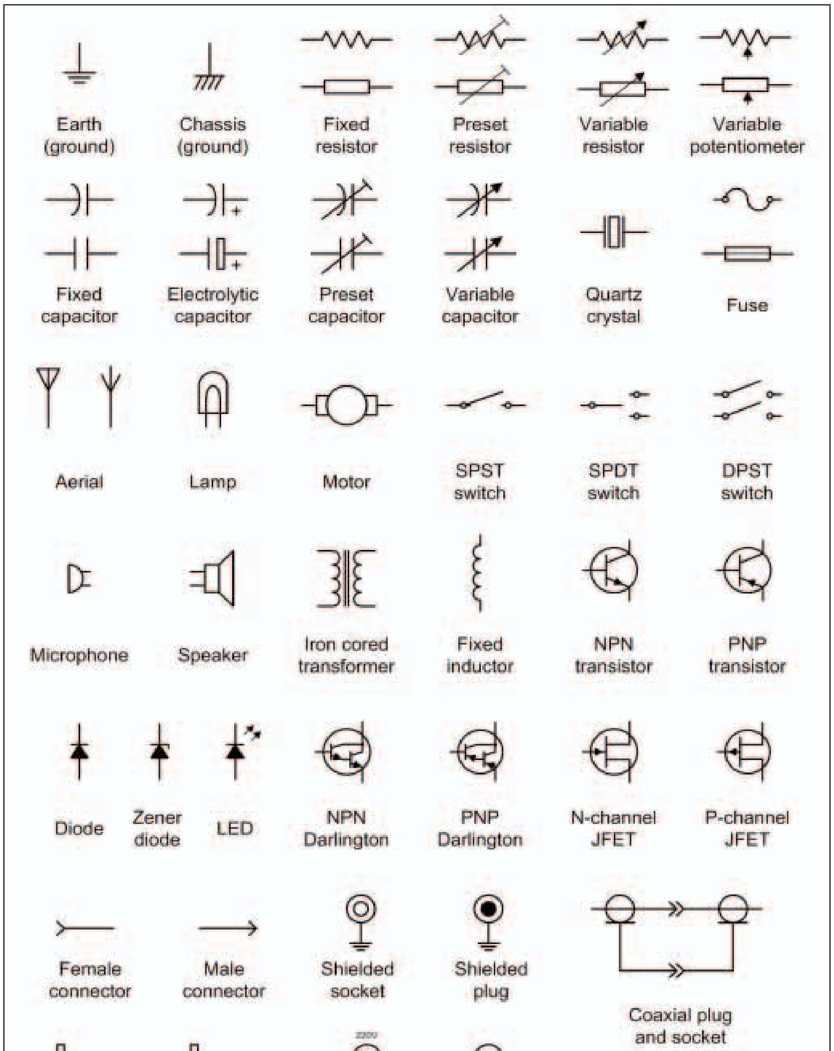


Fig.2.1. Selection of Symbols for electronic components

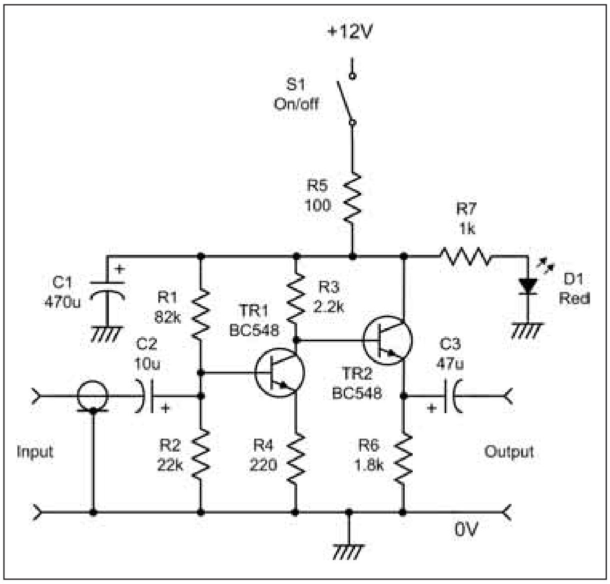


Fig.2.2. A simple circuit diagram

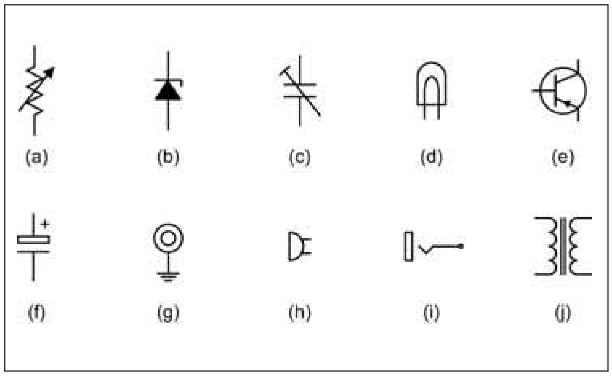


Fig.2.3. See question Q2.7

many lines connected to the same point) multiple connections to common, 0V, or ground may be shown using the appropriate symbol. The same applies to supply connections that may be repeated (appropriately labelled) at various points in the diagram.

A simple circuit diagram (an audio preamplifier) is shown in Fig.2.2. This circuit may be a little daunting if you haven't met a circuit like it before, but you can still glean a great deal of information from the diagram even if you don't know what the individual components do or how they work.

Look carefully at Fig.2.2 for a moment and you will notice that two transistors are used in the preamplifier, TR1 and TR2, and they are both BC548 types. If you now look closely at the circuit symbols shown in Fig.2.1, you should be able to identify TR1 and TR2 as *npn* transistors (look carefully at the direction of the arrow). Later in our *Teach-In* series we will explain how transistors work and what the differences are between *npn* and *pnp* types.

Next you should see that the circuit has an input (on the left) and an output (on the right). You should also notice that the input uses a shielded or screened (coaxial) cable. It's also worth noting that one of the two input connections is directly connected to one of the two output connections and this is also connected to chassis (ground) and 0V. We often refer to this as the *common* connection because it is common to both the input and output).

It should be obvious from the labelling, that the supply to the circuit is +12V and this is connected via switch S1, which allows the supply to be switched on (when the switch is closed) and off (when the switch is open).

There are seven resistors in the circuit, labelled R1 to R7 and three capacitors, labelled C1 to C3. All three capacitors are polarised electrolytic types and the positive terminal of each (marked with a "+" sign) must be connected with the indicated polarity. So, taking C1 as an example, the negative connection is taken to ground (0V) and the positive connection is taken to a more positive potential which appears at the junction of R5 with C1. In practice, the voltage dropped across C1 is about 10·5V (a little less than the full +12V supply).

Finally, you should note that there is a light emitting diode (l.e.d.) indicator, D1. This will become illuminated whenever S1 is closed. Current to supply the l.e.d. flows first through resistor R5 and then through R7.

Checkpoint 2.1

Circuit diagrams use standard conventions and symbols to represent the components and wiring used in an electronic circuit. Circuit diagrams provide a "theoretical" view of a circuit that is often different from the physical layout of the circuit to which they refer.

Series and Parallel Circuits

Later in this part we show you how Ohm's Law and Kirchhoff's Laws can be combined to solve more complex series-parallel circuits. However, before we do this, it's important to understand what we mean by "series" and "parallel" circuits. This section looks at some simple serial and parallel arrangements of resistors.

Fig.2.4a shows two resistors, R1 and R2, connected in series whilst Fig.2.4b shows two resistors, R1 and R2, connected in parallel. In each case, the equivalent resistance of the circuit (i.e. the one single resistor that could replace R1 and R2) is shown as resistor R.

In the series circuit shown in Fig.2.4a, the same current flows in each of the resistors and the value of R is given by the sum of the two resistances, R1 and R2. Hence, for the series case:

$$R = R1 + R2$$

In the parallel circuit shown in Fig.2.4b, the same voltage appears across each of the resistors and the reciprocal of the value of R (i.e. 1/R) is given by the sum of the reciprocals of the other two resistances, 1/R1 and 1/R2. Hence, for the parallel case:

$$\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2}$$

Questions 2.1

Here are a few questions on the circuit diagram shown in Fig.2.2 for you to try (answers at the end of this part):

Q2.1. Which capacitor is connected directly to 0V?
Q2.2. Which three resistors are connected directly to 0V?
Q2.3. What type of switch (d.p.d.t., d.p.s.t., s.p.d.t. or s.p.s.t.) is S1?
Q2.4. One side of the l.e.d. is connect ed to ground. True or false?
Q2.5. What is the value of R4?
Q2.6. What is the value of C2?
Q2.7. Fig.2.3 shows a few more circuit symbols for you to identify

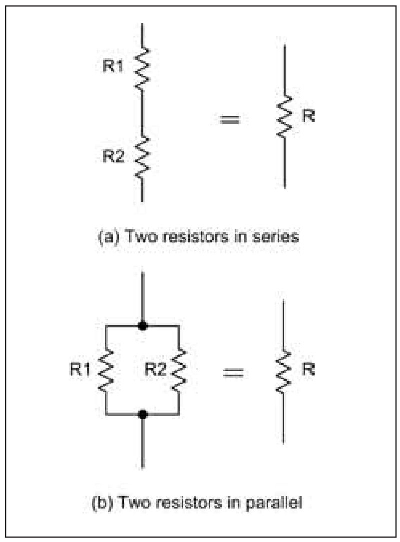


Fig.2.4 Series and parallel resistors

By applying a little mathematics to this result we can arrive at an equation that's a little easier to use, i.e.:

$$R = \frac{R1 \times R2}{R1 + R2}$$

The easiest way to remember this is "product divided by sum".

Example 2.1

Find the equivalent resistance of two 22Ω resistors if they are connected (a) in series and (b) in parallel.

In the series case (a), the equivalent resistance will be given by:

$$R = R1 + R2 = 22 + 22 = 44\Omega$$

In the parallel case (b), the equivalent resistance will be given by:

$$R = \frac{R1 \times R2}{R1 + R2} = \frac{22 \times 22}{22 + 22} = \frac{484}{44} = 11\Omega$$

Checkpoint 2.2

The equivalent resistance of two resistors connected in series can be found by simply adding together the individual values of resistance.

Question 2.2

Now see if you can determine the equivalent resistance of a circuit with several resistors connected together (answer at the end of this part):

Q2.8. Determine the resistance of each of the circuits shown in Fig.2.5.

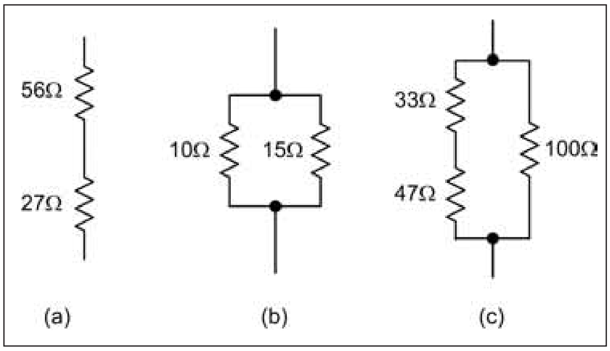


Fig.2.5. See Question Q2.8

Checkpoint 2.3

The reciprocal of the equivalent resistance of two resistors connected in parallel can be found by simply adding together the *reciprocals* of the individual values of resistance.

Checkpoint 2.4

The equivalent resistance of two resistors connected in parallel can be found by taking the *product* of the two resistance values and *dividing* it by the *sum* of the two resistance values (in other words, *product over sum*).

Kirchhoff's Laws

Used on its own, Ohm's Law is insufficient to determine the magnitude of the voltages and currents present in complex circuits. For these circuits we need to make use of two further laws: *Kirchhoff's Current Law* and *Kirchhoff's Voltage Law*.

Kirchhoff's Current Law states that the algebraic sum of the currents present at a junction (or *node*) in a circuit is zero – see Fig.2.6.

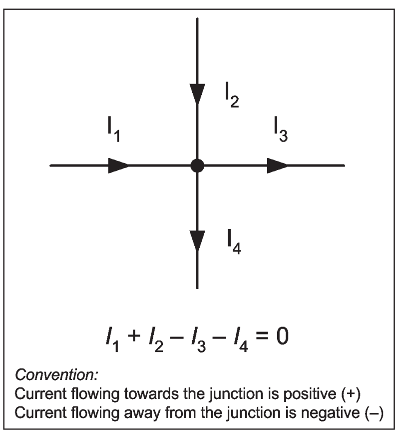


Fig.2.6. Kirchhoff's Current Law

Example 2.2

Determine the value of the missing current shown in Fig.2.7.

By applying Kirchhoff's Current Law in Fig.2.7, calling the unknown current *I*, and adopting the convention that currents flowing towards the junction are positive, we can say that:

$$+2A + 1{\cdot}5A - 4A - I = 0$$

Note that we have shown *I* as negative. In other words we have assumed that it is flowing away from the junction.

Re-arranging gives:

$$-0{\cdot}5 - I = 0$$

Thus $I = +0{\cdot}5A$

The positive answer tells us that *I* is flowing in the direction we assumed, i.e. *away* from the junction. Had we obtained a negative result this would have indicated that *I* flows in the opposite direction, i.e. *towards* the junction.

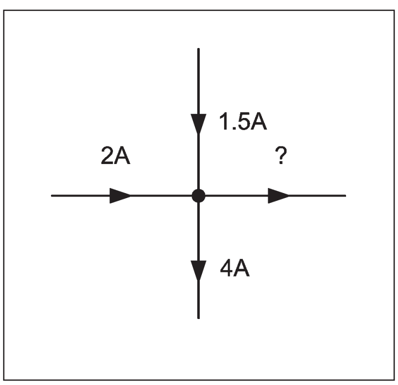


Fig.2.7. See Example 2.2

Checkpoint 2.5

Kirchhoff's Current Law says that the sum of the current flowing towards a junction must always be equal to the sum of the current flowing away from it. Note that it's important to take into account the direction of current flow in your calculations.

Kirchhoff's second, Voltage Law states that the algebraic sum of the potential drops present in a closed network (or *mesh*) is zero – see Fig.2.8.

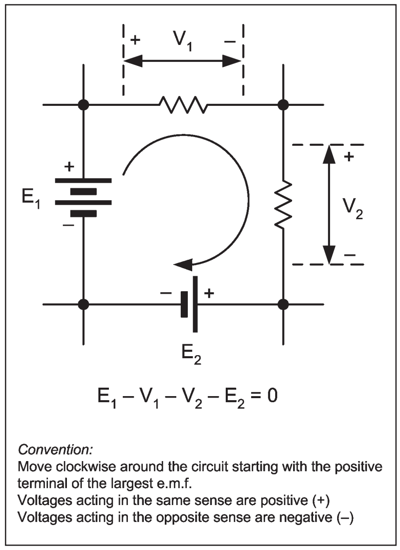


Fig.2.8. Kirchhoff's Voltage Law

Example 2.3

Determine the value of the missing voltage shown in Fig.2.9.

By applying Kirchhoff's Voltage Law in Fig.2.9, calling the unknown voltage *V* and starting at the positive terminal of the largest e.m.f. and moving clockwise around the closed network, we can say that:

$$+9V - V + 5V - 3{\cdot}6V = 0$$

Note that we have shown *V* as negative. In other words we have assumed that the more positive terminal of the resistor is the one on the left.

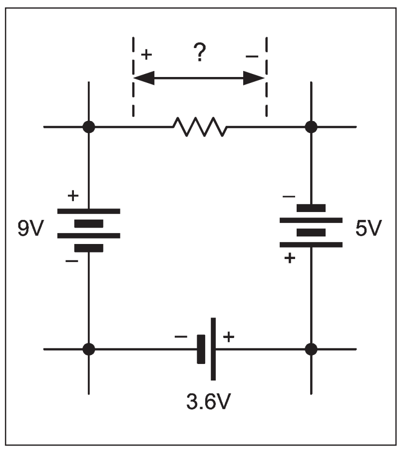


Fig.2.9. See Example 2.3

Re-arranging gives:

$10{\cdot}4\text{V} - V = 0$

From which:

$V = +10{\cdot}4\text{V}$

The positive answer tells us that we have made a correct assumption concerning the polarity of the voltage drop, *V*, i.e. the more positive terminal is actually on the left. Had we obtained a negative result this would have indicated that *V* was in the opposite sense, i.e. the more positive terminal is on the right.

Checkpoint 2.6

Kirchhoff's Voltage Law says that, in a closed circuit, the sum of the voltage drops must be equal to the sum of the e.m.f. present. Note, also, that it's important to take into account the polarity of each voltage drop and e.m.f. as you work your way around the circuit.

Questions 2.3

Now see if you can put Kirchhoff's Laws into practice by referring to Fig.2.10 and answering the following questions (answers at the end of this part):

Q2.9. Determine the voltages dropped across R1 and R2 (and in each case indicate the polarity of the voltage).

Q2.10. Determine the current flowing in each battery (and in each case indicate the direction of current flow).

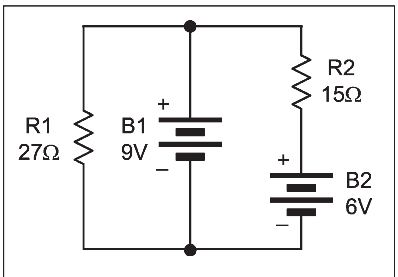


Fig.2.10. See Question Q2.9

Voltage Divider

The voltage divider (see Fig.2.11) is an extremely useful circuit since, by selecting appropriate values for the two resistors, R1 and R2, it allows you to obtain a fraction of the input voltage, V_{IN}. Note that the circuit works equally well with a.c., or d.c. signals.

The value of output voltage, V_{OUT}, produced by the voltage divider is given by the relationship:

$$V_{OUT} = V_{IN} \times \frac{R2}{R1 + R2}$$

As an example, suppose that we need to produce a voltage of precisely 5V from a 15V d.c. supply. We would need to make the value of R1 twice that of R2. Values of 2kΩ for R1 and 1kΩ for R2 would do the trick. Note that we would produce the same output voltage (but at the cost of taking more current from the input) by using 200Ω for R1 and 100Ω for R2.

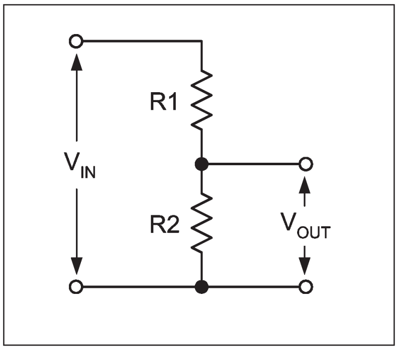


Fig.2.11. A voltage divider

Current Divider

The current divider (see Fig.2.12) is another useful circuit. By selecting appropriate values for the two resistors, R1 and R2, you can obtain a fraction of the input current, I_{IN}. Like the voltage divider, the circuit works equally well with a.c. or d.c. signals.

The value of output current, I_{OUT}, produced by the current divider is given by the relationship:

$$I_{OUT} = I_{IN} \times \frac{R1}{R1 + R2}$$

As an example, suppose that we need to produce a current of precisely 5mA from a 15mA input current. We would need to make the value of R2 twice that of R1. Values of 1Ω for R1 and 2Ω for R2 would do the trick. Note that we would produce the same output current (but at the cost of a higher voltage drop) by using 10Ω for R1 and 20Ω for R2.

Basic Measurements – The Multimeter

If you carried out the Practical Investigations in Part 1 you will have already made some basic measurements on an electronic circuit. This section is designed to provide you with a little more information on using a multimeter and why digital types are often preferred over analogue instruments.

For practical measurements on electronic circuits it is often convenient to combine the functions of a voltmeter, ammeter and ohmmeter into a single instrument (known as a multi-range meter or simply a *multimeter*). In a conventional multimeter as many as eight or nine measuring functions may be provided with up to six or eight ranges for each measuring function.

Besides the normal voltage, current and resistance functions, some meters also include facilities for checking transistors and measuring capacitance. Most multi-range meters normally operate from internal batteries and thus they are independent of the mains supply. This leads to a high degree of portability which can be all-important when measurements are to be made away from a workshop or laboratory.

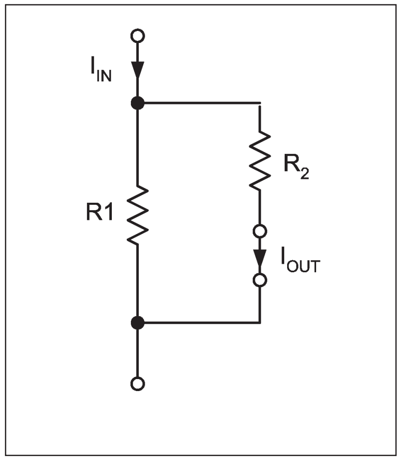


Fig.2.12. A current divider

Analogue Meters

Analogue instruments employ conventional moving coil meters and the display takes the form of a pointer moving across a calibrated scale. This arrangement is not so convenient to use as that employed in digital instruments because the position of the pointer is rarely exact and may require interpolation.

Analogue instruments do, however, offer some advantages, not the least of which lies in the fact that it is very easy to make adjustments to a circuit whilst observing the relative direction of the pointer; a movement in one direction representing an increase and in the other a decrease.

Despite this, the principal disadvantage of many analogue meters is the rather cramped, and sometimes confusing, scale calibration. To determine the exact reading requires first an estimation of the pointer's position and then the application of some mental arithmetic based on the range switch setting.

Digital Meters

Digital meters, on the other hand, are usually extremely easy to read and have displays that are clear, unambiguous, and capable of providing a very high resolution. It is thus possible to distinguish between readings that are very close. This is just not possible with an analogue instrument.

Another very significant difference between analogue and digital instruments is the input resistance that they present to the circuit under investigation when taking voltage measurements. The resistance of a reasonable quality analogue multi-range meter can be as low as 50kΩ on the 2·5V d.c. range.

With a digital instrument, on the other hand, the input resistance is typically 10MΩ on all the d.c. voltage ranges. The digital instrument is thus to be preferred when accurate readings are to be taken. This is particularly important when measurements are to be made on high resistance circuits.

When using a multimeter to make measurements of voltage in a circuit, it is important to remember to select the correct voltage range and to connect the meter leads across (i.e. in parallel with) the component for which the measurement is to be made.

Conversely, when making current measurements it is necessary to select the correct

Photo 2.1 Analogue (left) and digital (right) multimeters

current before breaking the circuit and inserting the meter leads in series with the component for which the current measurement is to be made.

Practical Investigation 2.1

Objective: To investigate a simple series-parallel circuit and to verify Kirchhoff's Laws.

Components and Materials:
Breadboard, 9V d.c. power source (either a PP9 9V battery or an a.c. mains adapter with a 9V 400mA output), digital multimeter with test leads, resistors of 330Ω and 470Ω, 680Ω, insulated wire links (various lengths), assorted crocodile leads, short lengths of black, red, and green insulated solid wire.

Circuit diagram: See Fig.2.13

Wiring diagram: See Fig.2.14

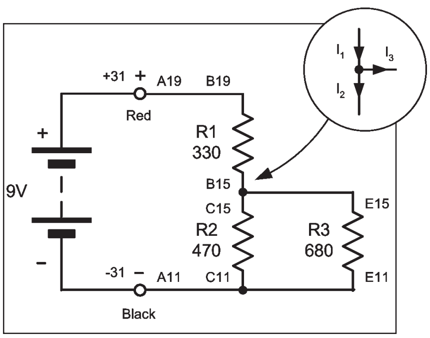


Fig.2.13. Circuit diagram for the series-parallel circuit investigation.

Procedure:
The required breadboard wiring is shown in Table 2.1.

Connect the circuit as shown in Fig.2.14. Before switching on the D.C. supply or connecting the battery, check that the multimeter is set to the D.C. 200V range. Switch on (or connect the battery), switch the multimeter on and measure the supply voltage (this should be close to 9V) as well as the voltage dropped across each of the resistors, R1, R2 and R3. Record your results in Table 2.2.

Switch the multimeter to the D.C. 200mA range and, by removing one end of each resistor in turn and inserting the meter in the circuit, measure and record the current flowing in each of the resistors; R1, R2, and R3. Record your results in Table 2.2.

Calculations:
Use Kirchhoff's Current Law to write down an expression for the currents at the junction of R1, R2 and R3 (see inset in Fig.2.13). Then substitute the values that you obtained by measurement and check that Kirchhoff's Current Law is obeyed.

Use Kirchhoff's Voltage Law to write down an expression for the d.c. supply voltage and the voltages developed across R1, R2 and R3. Then substitute the values that you obtained by measurement and check that Kirchhoff's Voltage Law is obeyed.

Conclusion:
Comment on the accuracy of your results. Have you been able to confirm that Kirchhoff's Laws are obeyed?

Energy and Power

Like all other forms of energy, electrical energy is the capacity to do work. Energy can be converted from one form to another. An electric fire, for example, converts electrical energy into heat. A filament lamp converts electrical energy into light, and so on. Energy can only be transferred when a difference in energy levels exists.

Power, *P*, is the rate at which energy is converted from one form to another and it is measured in *Watts*. The larger the amount of power the greater the amount of energy that is converted in a given period of time.

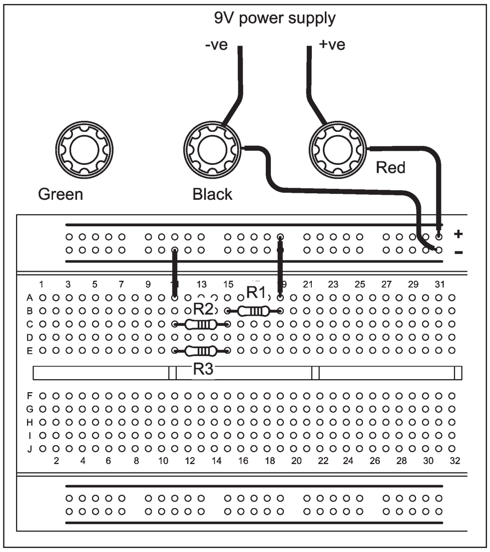


Fig.2.14. Wiring diagram for the series-parallel circuit investigation.

Table 2.1

Step	Connection, link or component	From	To
1	–9V supply	–9V	Black terminal
2	+9V supply	+9V	Red terminal
3	Black wire	Black terminal	–31
4	Red wire	Red terminal	+31
5	Yellow link	A11	–11
6	Green link	A19	+19
7	R1 330Ω	B15	B19
8	R2 470Ω	C11	C15
9	R3 680Ω	E11	E15

Table 2.2: Voltage and Current Measurements

Test point	Notation	Voltage (V)
D.C. supply voltage (9V)	E	
Voltage dropped across R1	V_1	
Voltage dropped across R2	V_2	
Voltage dropped across R3	V_3	
Test point	**Notation**	**Current (mA)**
Current flowing in R1	I_1	
Current flowing in R2	I_2	
Current flowing in R3	I_3	

Now, 1 Watt = 1 Joule per second or:

$$\text{Power, } P = \frac{\text{energy, J}}{\text{time, t}}$$

$$\text{thus: } P = \frac{J}{t} \quad W$$

The unit of energy is the *Joule*. Then, from the definition of power:

1 Joule = 1 Watt × 1 second

hence:

Energy, J = (power, P) × (time, t) with units of (Watts × seconds)

thus: $J = P\,t \quad W$

Joules are thus measured in *Watt-seconds*. If the power was to be measured in kilowatts and the time in hours, then the unit of electrical energy would be the *kilowatt-hour, kWh* (commonly known as a *unit of electricity*). The electricity meter in your home records the number of kilowatt-hours. In other words, it indicates the *amount of energy* that you have used.

Example 2.4

A computer power supply provides an output of 200W for 20 minutes. How much energy has it supplied to the computer?

Here we will use $J = P\,t$

where P = 200W and t = 20 minutes =

20 × 60 = 1,200s

Thus:

J = 200 × 1,200 = 240,000 J = 240kJ

Circuit Construction Techniques

Finally, it's time to take a break from calculations and circuit theory in order to take a brief look at the different methods that can be used to construct electronic circuits. If you've attempted our first two Practical Investigations you will already have had experience of one of these!

Various methods are used for building electronic circuits. The method that's actually chosen for a particular application depends on a number of factors, including the available resources and the scale of the production.

Techniques used for large-scale electronic manufacture generally involve fully automated assembly, using equipment that can produce complex circuits quickly and accurately and at very low cost with minimal human intervention. On the other extreme, if only one circuit is to be built then a hand-built prototype is much more appropriate.

It is also worth noting that, when a circuit is designed for a commercial application, it will invariably be tested using computer simulation techniques before a prototype is manufactured.

An example of point-to-point wiring construction is shown in Photo 2.2. This is a technique that is nowadays considered obsolete with the advent of miniature components, printed circuit boards and integrated circuits.

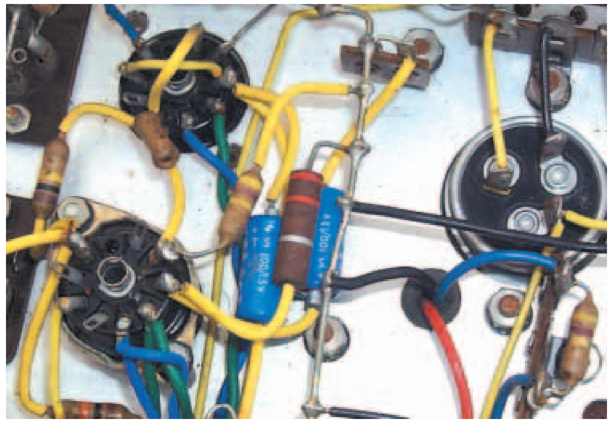


Photo 2.2. Point-to-point wiring construction

The example shown in Photo 2.2 is the underside of a valve amplifier chassis dating back to the early 1960's.

An example of breadboard construction is shown in Photo 2.3. This "solderless" construction technique is often used for assembling and testing simple circuit arrangements and is the technique used for our Teach-In Inves-tigations.

The advantage of this technique is that changes can be quickly and easily made to a circuit and all of the components can be re-used. Disadvantages of breadboard construction are that it is unsuitable for permanent use and also unsuitable for complex circuits. The example assembly shown in Photo 2.3 is for a partly constructed transistor amplifier.

An example of matrix board (also known as stripboard) construction is shown in Photo 2.4. This low-cost technique avoids the need for a printed circuit but is generally only suitable for one-off prototypes. The matrix board consists of an insulated board into which a matrix of holes are drilled with copper tracks arranged as strips on the reverse side of the board.

Component leads are inserted through the holes and soldered into place. Strips (or tracks) are linked together with short lengths of tinned copper wire (inserted through holes in the board and soldered into place on the underside of the board). The copper tracks can be broken (cut) at various points as appropriate.

Note that a suitable rating for a soldering iron for light electronic work (matrix board and small printed circuit boards) is typically between 15W and 25W. Larger soldering irons (particularly those that are not temperature controlled) may cause damage to tracks, pads and components.

The advantage of matrix boards is that they avoid the need for a printed circuit board (which may be relatively expensive and may take some time to design). Disadvantages of matrix board construction are that it is usually only suitable for one-off production and the end result is invariably less compact than a printed circuit board. The matrix board shown in Photo 2.4 forms part of a prototype a.c. voltmeter.

Photo 2.5 shows an example of printed circuit board construction. This technique is ideal for volume manufacture of electronic circuits where speed and repeatability of production are important. Depending on the complexity of a circuit, various types of printed circuit board are possible.

The most basic form of printed circuit (and one which is suitable for home construction) has copper tracks on one side and components mounted on the other. More complex printed circuit boards have tracks on both sides (they are referred to as "double-sided") whilst boards with up to four layers are used for some of the most sophisticated and densely packed electronic equipment (for example, computer motherboards).

The single-sided printed circuit board shown in Photo 2.5 is a mains filter removed from a computer printer. Note

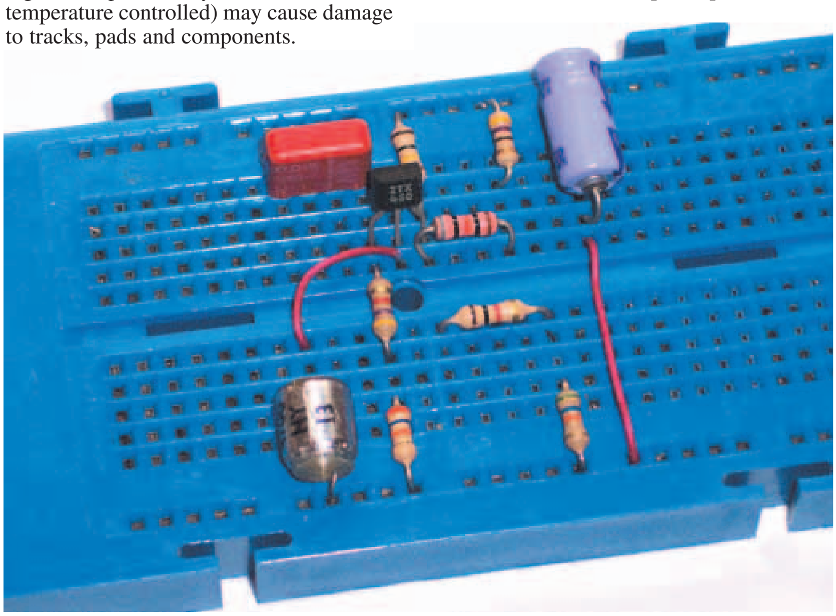


Photo 2.3. Breadboard construction

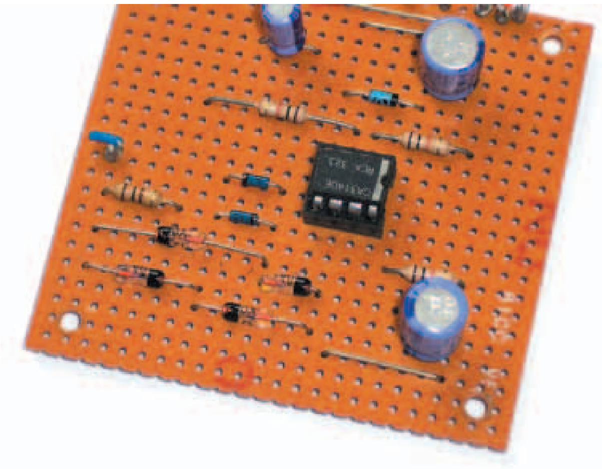


Photo 2.4. Matrix board construction

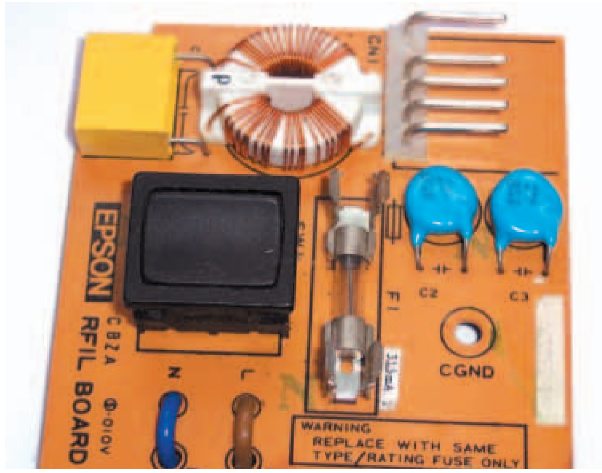


Photo 2.5. Printed circuit board construction

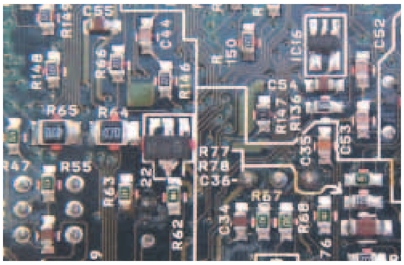


Photo 2.6. Surface mounting construction

that this is shown viewed from the component side rather than the track side.

An example of surface mounting construction is shown in Photo 2.6. This technique is suitable for sub-miniature leadless components. These are designed for automated soldering directly to pads on the surface of a printed circuit board. This technique makes it possible to pack the largest number of components into the smallest space but, since the components require specialised handling and soldering equipment, it is not suitable for home construction, nor is it suitable for hand-built prototypes.

The example shown in Photo 2.6 is part of the signal processing circuitry in a large PC display.

Answers to Questions in Part 2

Q2.1. C1
Q2.2. R2, R4 and R6
Q2.3. s.p.s.t.
Q2.4. True
Q2.5. 220Ω
Q2.6. 10µF
Q2.7:
a) variable resistor
b) Zener diode
c) preset capacitor
d) lamp
e) *pnp* transistor
f) electrolytic capacitor
g) shielded socket
h) microphone
i) open jack socket
j) iron-cored transformer
Q2.8:
a) 83Ω
b) 6Ω
c) 44.4Ω
Q2.9. Voltage dropped across R1:
9V (positive at the top end)
Voltage dropped across R2:
3V (positive at the top end)
Q2.10. Current flowing in B1:
0·53A (flowing upwards)
Current flowing in B2:
0·2A (flowing downwards)

Next Month

We shall be introducing semiconductors and investigating the use of diodes in power supply circuits. In the meantime, don't forget you can check your understanding by taking our online test for Part 2 which you will find at **www.miketooley.info/teach-in/quiz2.htm**.

Good luck!

Part One – Page 766 Fig.1.9. The third contact (way) on the lower group of the 2-pole 3-way switch circuit symbol is missing and should be the same as the "linked section" above it.

OVER £600s WORTH OF TEACH-IN '06 PRIZES DONATED BY RAPID ELECTRONICS

At the end of the Teach-In '06 course there will be an on-line multiple-choice test covering the entire series. Successful completion of the final test will lead to the award of a personalised certificate and students with the highest marks will go forward to a tie-break for the award of tool kits, kindly donated by Rapid Electronics. Just follow the course and you could be a winner.

1st Prize: 72-piece tool kit worth £323.00

The kit comprises a very wide range of high quality hand tools that should last a lifetime. Everything from a professional digital l.c.d. multimeter with capacitance, frequency, temperature and transistor h_{FE} measurement in addition to a.c. and d.c. voltage and current and resistance ranges – 32 ranges in all – to a Nimrod butane gas soldering iron, soldering and desoldering aids, screwdrivers, files, pliers, sidecutters, wire strippers, even hex keys and combination spanners etc. The set is ideal for commonly encountered electronic, electrical and hardware tasks and comes in a ruggged ABS/aluminium carrying case.

Runners Up Prizes: 21 tool kits in zipped cases each worth £13.51

The kits each comprise eight commonly used hand tools, including pliers, side cutters, a wire stripper, screwdrivers, a stripboard cutter and trimming tool in a black reinforced, zip fastening, padded carrying case. Ideal for the student, hobbyist or technician to keep handy for electronic or electrical tasks.

Constructional Project

Propeller Monitor

John Becker

Know the power and revolution rate developed by your propeller or motorised model

SOME time ago a reader rang and asked if we had ever published a design which would measure the rotation rate of the propeller on his model boat, and the propulsion power that it developed. The answer was that we hadn't, but it set the author thinking. The design presented here describes one of several possible answers and is suitable for use with a wide variety of model boats or planes.

Requirements

Sensing the rotation rate of a propeller or fan is easy – place an l.e.d. on one side of the prop and an optosensor on the other. As the prop rotates its blades cut the light beam reaching the sensor, causing an electronic pulse to be developed. The rotation rate is then the number of pulses counted in a given time, divided by the number of blades on the prop.

Mechanically, the simplest way to detect the prop's power would be to use a weighing machine on its side and to sense the pressure of the powered boat (or plane) pushing against it. Similarly, a fisherman's portable scale could sense the model's pull on it.

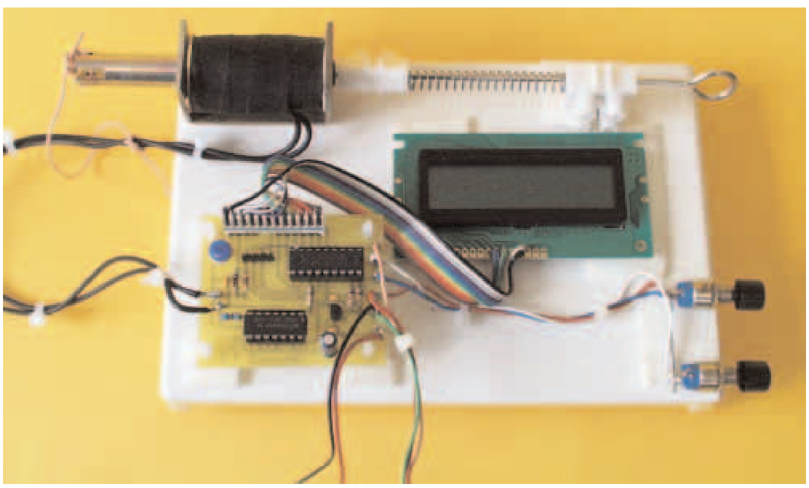
What the reader was after, though, was an electronic means of showing both the prop's rev count and its propulsive force on a liquid crystal display.

Spring Action

The solution for sensing a prop's force described here is spring-based. It was apparent that a spring to which the model was connected in some way could become part of a tuned inductance oscillator circuit. The coiled spring would form an inductor whose value changed with the spring's expansion or compression.

Experiments proved the basic validity of the idea, but the resulting frequency changes were too slight to be used meaningfully. However, further experiments showed that a spring could be used in conjunction with a separate coil and a ferromagnetic bar.

Inserting the bar partly into the coil and then pushing or pulling it against the spring, its penetration of the coil changes in relation to the amount of force applied. The effect is that the overall inductance of the coil changes more significantly for a given amount of force. This causes greater frequency changes in an oscillator circuit built around it.



Prototype Propeller Monitor test bed assembly

Further experiments showed that a solenoid and its bolt were ideal for use as a mechanically variable inductor. Its implementation is described after the electronic circuit has been discussed.

Circuit Diagram

The complete circuit diagram for the Propeller Monitor is shown in Fig.1.

At the heart of the circuit is a PIC16F628 microcontroller, IC1. It measures the frequencies output by the revs and inductive sensors, processing the values and outputting the results via Port B to liquid crystal display X1.

The revs sensor is based on the Schmitt trigger optosensor IC3. It detects whether or not it is receiving light from l.e.d. D2. As the propeller rotates between the two devices, the sensor's output goes high or low in response to the changing light levels.

These pulses are input to PIC pin RA4 and counted in software over repeating periods of one second. At the end of each second, the count is divided by the number of prop blades to give the overall rotation rate. This is displayed as two values, revs per second (RPS) and revs per minute (RPM).

The RPS rate is shown to the nearest whole number. The RPM rate is calculated by multiplying the RPS rate by 60. The resolution is thus in steps of 60 units. Decimal places are not used in this simple design.

The maximum pulse count is in excess of 5kHz, e.g. 100,000 RPM for a 3 bladed propeller.

Coiled Oscillator

The force sensing oscillator is formed around Schmitt inverting gate IC4a. The solenoid coil is represented as inductance L1. The oscillation frequency is set by L1's value in relation to that of capacitor C4 and resistor R4. The configuration was inspired by part of Thomas Scarborough's *Beat Balance Metal Detector* (May '04).

The output from IC4a is buffered by IC4b and fed to PIC pin RB6. Resistor R5 prevents interaction between the IC4b signal and inputs from a PIC programming board if the PIC is programmed in situ

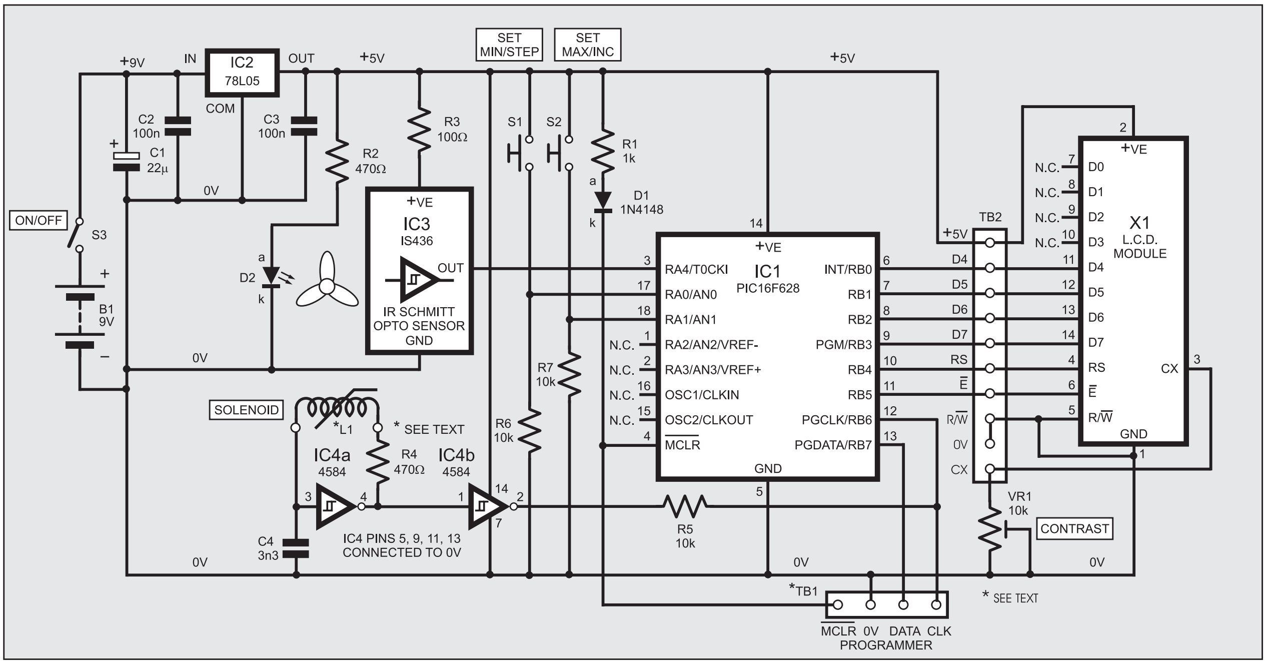


Fig.1. Complete circuit diagram for the Propeller Monitor

(pre-programmed PICs are available as stated later).

PIC pin RB6 is programmed as the input to the TMR1 16-bit timer, which is used here in counter mode, with a maximum count value of 65535. The counter is sampled once every second and that value is effectively a frequency count in Hertz.

The term "effectively" is used because the sampling rate is not quite one second. The PIC is run at about 4MHz as set by its internal oscillator mode. Dividing 4MHz down into a rate of exactly one second cannot be done evenly, and the nearest division ratio has been used (but theoretically accurate to within about one part per thousand – subject to the accuracy of the PIC's oscillator).

The frequency range on the prototype with the solenoid bolt fully in and fully out is about 7500Hz to 8500Hz. Once an initial warm-up period of about 10 to 15 minutes has elapsed, the coil-generated frequency was found to be very stable.

Calculations

The PIC's TMR0 timer is used to set the sampling rate. At the end of each second, the prop revs are calculated, as above, and the equivalent prop force value.

The force value depends on the amount by which the solenoid bolt has been pushed by the model into the solenoid's coil. The action is restricted by the strength of the spring against which the bolt is forced.

In this context there are many compression springs with different strengths available. The type used in the prototype allowed a full-scale pressure maximum equivalent to a weight of about 1kg. Springs of greater or lesser strengths may be used to change the range, and hence the unit's sensitivity to prop-induced pressure.

The force experienced by the spring is calculated by relating the immediate frequency generated by the coil to the minimum and maximum possible frequencies when the bolt is fully in or fully out. The answer is then converted to a weight equivalent. The maximum weight measurable is set by the user. It is relative to the spring strength and can be in any weight units, grams, kilograms, pounds, ounces, Newtons, Pascals, etc.

Other Circuit Aspects

Two switches, S1 and S2, are provided via which the various parameters can be set. These include:

- Blade Count
- Maximum pressure frequency
- Minimum pressure frequency
- Maximum force units (up to 59,000)

The unit is intended to be powered by a 9V battery, e.g. PP3. Regulator IC2 reduces the 9V to 5V to suit the rest of the circuit.

Preset VR1 sets the l.c.d. screen contrast level.

The four connections jointly marked as TB1 are the pins via which the PIC may be programmed in situ via a suitable programmer, such as the author's *Toolkit TK3*. Resistor R1 and diode D1 prevent power line conflict caused by PIC programming voltage levels.

Construction

Details of the printed circuit board component and track layouts are shown in Fig.2. This board is available from the *EPE PCB Service* code 544.

Before starting assembly, cut from the board the two marked strips at one end. These are used to hold the optosensor components and are ultimately positioned either side of the propeller.

Assemble in the usual order of link wire, dual-in-line (d.i.l.) sockets, and then in ascending order of component size. Observe the correct orientation of the semiconductors and capacitor C1. Do not insert the d.i.l. i.c.s, or connect the l.c.d., until the voltage output from the regulator, IC2, has been proved to be 5V (within a few millivolts).

Temporarily connect the two optosensor strips back to the main board via shortish wires.

Once the boards and the power supply output have been fully checked for accuracy, and with power disconnected, insert the pre-programmed PIC IC1, and Schmitt gate IC4. Also connect the l.c.d., whose typical pinouts are shown in Fig.3. Reconnect the power supply and recheck that the 5V line is still correct.

Testing

With everything connected and the power again switched on, the PIC goes through a brief initialisation routine in which it recalls various values from its non-volatile memory. At first switch on, these will be those last used by the author and may cause erroneous values to be shown on the l.c.d. screen. Adjust preset VR1 until the l.c.d. shows good-contrast information on its display lines. The following is an example display:

On the top line are shown the RPS and RPM captions, a value having several digits (up to five) which is the approximate frequency sensed from solenoid coil oscillator, letter F (meaning frequency), and a hash (#) symbol indicating blades.

On line two the values for RPS and RPM will be zero until such time as the optosensor assembly is put into use. The next value

RPS	RPM	8500F	#
0	0	987W	3

is the calculated weight relative to the displayed frequency value and other values held in memory but not displayed. It is followed by the letter W (meaning weight), and the value of 3 indicating the number of prop blades currently selected.

The units of weight (e.g. gms, kgs, etc) are whatever you choose them to be. Their notation type is not displayed.

Variously slide the solenoid bolt in and out of its coil housing, observing the result-

COMPONENTS

See SHOP TALK page

Resistors

R1	1k
R2, R4	470Ω (2 off)
R3	100Ω
R5 to R7	10k (3 off)

All 0·25W 5% carbon film

Potentiometer

VR1	10k min round preset

Capacitors

C1	22μ radial elect. 16V
C2, C3	100n ceramic disc, 5mm pitch (2 off)
C4	3n3 ceramic disc, 5mm pitch (see text)

Semiconductors

D1	1N4148 signal diode
D2	red l.e.d., high-brightness
IC1	PIC16F628 microcontroller, pre-programmed (see text)
IC2	78L05 +5V 100mA voltage regulator
IC3	IS436 Schmitt trigger optosensor
IC4	4584 hex Schmitt trigger inverter

Miscellaneous

L1	solenoid (see text)
S1, S2	min. push-to-make switch (2 off)
S3	min. s.p.s.t. toggle switch
X1	2-line 16-character (per line) alphanumeric l.c.d. module

Printed circuit board, available from the *EPE PCB Service*, code 544; 14-pin d.i.l. socket; 18-pin d.i.l. socket; 9V battery and clip; compression spring (see text); kitchen skewer, smooth (see text); 6-way 30A terminal strip; plastic case to suit (see text); hardware mounting frame (see text); 1mm terminal pins; connecting wire; solder, etc.

Approx. Cost Guidance Only **£27** *excl case, solenoid and batts*

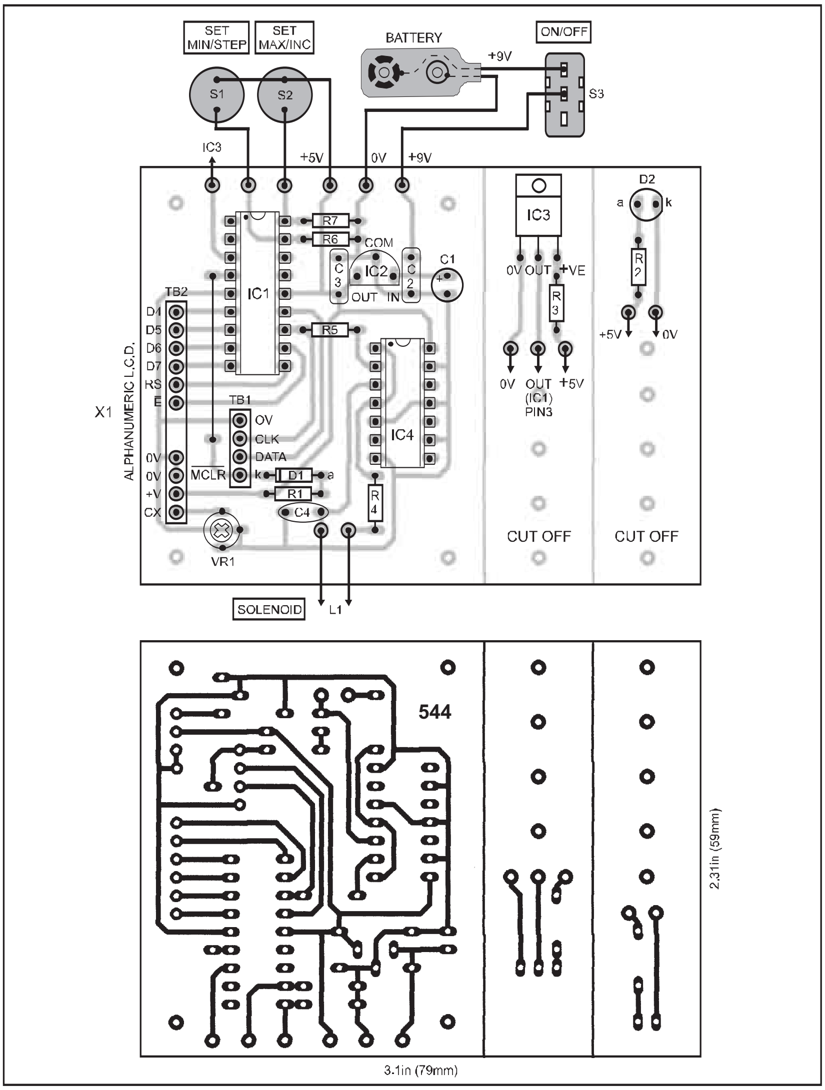
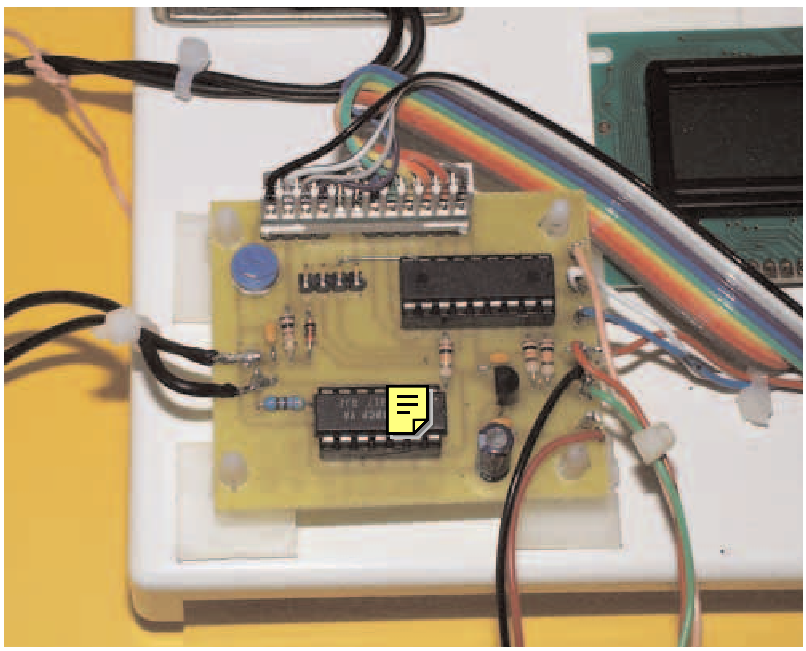


Fig.2. Printed circuit board component and track layout. Note the two sub-sections which are to be cut off



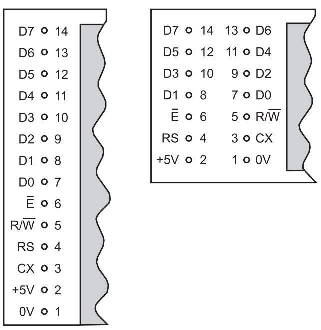


Fig.3. Alternative l.c.d. pinouts

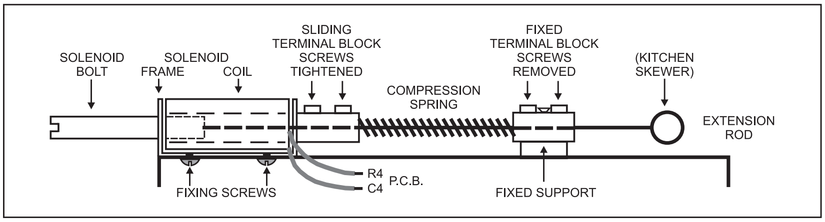


Fig.4. Suggested solenoid and spring assembly

ing numbers on the l.c.d. screen.

If you have a signal generator, set it for a 0V/5V output of about 10Hz. Do not exceed the 0V/5V voltage limit.

Adjust the signal generator's frequency and observe the RPS and RPM values changing in response. They have no affect on the coil's frequency.

Solenoid Assembly

Guidance on the solenoid assembly is given in Fig.4. Precise details are left to the user as they depend on the solenoid type, and the way in which it is intended to use the sensor. The prototype's solenoid came from the author's "spares" box and its origin is unknown. It measures 50mm × 25mm × 25mm and its bolt is 44mm × 11mm. Its voltage specification should be 5V or greater but is otherwise unimportant.

It is vital to note that the assembly depends on the solenoid having not only the bolt, but also a small access hole to the bolt from the opposite end. It seems likely, though, that all solenoids will have such a hole as an air vent behind the bolt.

It is suggested that you do a "rough lash-up" of the assembly on a wooden strut before finally deciding on what you wish to do. The details in Fig.4 are based upon that assumption.

Selection of the spring depends on the pressure exerted by the model. It is recommended that several strengths be obtained and experimentation carried out.

Spring To It

The spring used in the prototype was a stainless steel compression type, 54mm long, compressing fully to about 23mm under a weight of around 1kg. Its diameter is about 7mm and is specified as having a compression rate of 0.29 N/mm (Newtons per millimetre – a definition not instinctively known to the author).

Although this was purchased from a major component distributor as a precision spring, it was later discovered that some motor spares shops can also supply a range of springs that may be suitable. The major DIY stores in the author's area did not stock springs.

The extension rod indicated in Fig.4 was a smooth kitchen skewer such as is used in cooking. It was 17cm long, with a diameter of 2mm, fitting freely into the solenoid's rear access hole without friction. Its looped end conveniently provides protection from injury.

The electrical junction blocks used to mount it were 30A types whose terminals allowed the skewer to slide in easily, again without friction.

Secure the solenoid to the intended mount via the holes provided in its robust metal frame. Push the bolt fractionally into the solenoid, sufficient to prevent it dropping out, yet not cause significant friction in the early stages of coming under active pressure.

Insert the skewer into the rear terminal block, push on the spring, then the second terminal block. Next carefully push the skewer into rear of the solenoid until it meets the end of the bolt. Push the terminal block up to meet the solenoid frame and tighten down its locking screw.

Now slide the rear terminal block along until it just starts to put pressure on the spring. Screw down the block at that point, using a suitably thick spacer to hold the skewer horizontally in line with the solenoid hole (an empty i.c. socket was suitable for the prototype). Remove the terminal screws to prevent them being a cause of friction on the skewer, which must be allowed to slide smoothly through this block.

Push the bolt into the solenoid, observing the spring compression smoothness, and the return of the bolt to its starting position when pressure is removed. Adjustments can be made to the assembly following active trials.

If the assembly is now stood vertically, items of known weight can be balanced on the bolt to establish the weight at which the spring is fully compressed. It is that value which the software needs to be told when alignment values are set into the PIC via switches S1 and S2.

Alignment

There are two sets of data to be entered into the PIC. The first set is for the prop blade count, and the maximum weight for full spring compression as derived according to the previous paragraph.

This mode can only be entered when the unit is being switched on. *Before* switch-on, press S1 and hold it pressed. Switch on the power, wait until the l.c.d. screen shows the message SET BLADE COUNT, followed by the current value (3 is the default until changed), then release S1.

Now pressing S2 and holding it pressed, the blade count value will slowly step through its cycle, from 3 to 9, then rolling over to 1 and upwards again. Release S2 when the value you want is seen. If you overshoot, continue the cycle until the correct number reappears.

Next press S1 again. The software now enters the weight setting mode, in which the message SET WEIGHT is shown followed by a decimal value. The default at this time is shown as decimal 01000 (1kg for the prototype).

An asterisk is shown under the lefthand digit, indicating that this digit can now be changed using switch S2. Do so, releasing the switch when the desired value is shown. The range is 0 to 9, then rollover, etc.

Pressing S1 now steps the asterisk to the next digit. Change its value as before. Continue the S1/S2 procedure for all five digits. On the next press of S1, the blade and weight data are stored to the PIC's non-volatile memory (EEPROM) where it remains even after switch off. The program then enters the normal monitoring mode.

Note that the maximum weight value that can be set is 49,999. If the lefthand digit is set to a value greater than 5, it will be set back to 4 when the data is stored.

The settings may be changed at any later time by the same procedure.

It is suggested that you regard grams as the weight type whose value is entered since the range consists of small steps. Remember that the unit does not use decimal places, so weight units in pounds would have a very limited resolution in relation to the solenoid bolt position.

Next Test

With the required settings now in use, the pressure sensor can be tested more meaningfully, during which its minimum and maximum frequency values are set. These can be set at any time that the unit is in normal monitoring mode.

To set the minimum frequency value, ensure that the spring has allowed the bolt to be pushed back to its no-load position (nearly out of the solenoid). Wait a moment for the frequency to stabilise in this position, then press S1. This stores that value to the EEPROM.

By hand, now push the bolt in as far as it will go. Wait for stability again, and press S2 to cause the maximum frequency to be stored. Releasing the bolt, the frequency should return to the minimum value, and the weight value shown on line two should read zero. If it is slightly higher than this, press S1 again.

Pushing the bolt fully in again, the maximum weight value you have entered should be shown.

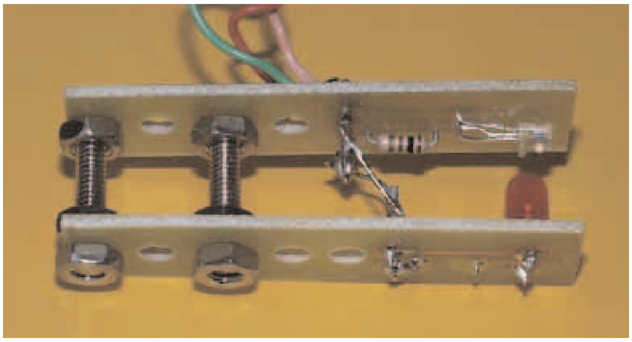
Each pressing of S1 and S2 in this mode is accompanied by a message confirming that data has been stored.

The actual frequencies generated will depend on the solenoid characteristics. The prototype's span of about 7500Hz to 8500Hz gave a range of about 1000Hz, well suited to a maximum weight value of 1kg (1000gms). The range may be modified by changing the value of capacitor C4 or resistor R4, but preferably C4.

Increasing C4, to 4·7nF (4700pF) for example, reduces the frequency. Reducing C4, to 2·2nF (2200pF) for example, raises the frequency.

In Use

For practical use with a model boat, it is recommended that the outer end of the solenoid bolt should have a disc attached, against which the boat can push. Covering the disc with a non-slip material, such as foam rubber or a large tap washer, would be helpful in maintaining the boat's contact with the plunger. The bolt is likely to have a slot and screw hole in its outer end which could be useful in making attachments to it. As an alternative system, and to use the unit with a model plane, glue the skewer to the solenoid and attach the model to the skewer



Prototype rev. sensor assembly. Other techniques exist

so that it pulls the bolt into the solenoid rather than pushing it in.

The solenoid's waterproofness is doubtful, and so it should not be put under water. It is best to enclose the coil area in a waterproof cover to prevent splashes getting into it. It would also seem prudent to occasionally use light oil to lubricate the moving parts and prevent corrosion.

The optosensor has to be used under water if propulsion power and rev counts are to be simultaneously assessed. Take great care in ensuring that this assembly is waterproofed. Any exposed electrical connections **must** be fully protected against water ingress. The use of hot melt glue is suggested.

Avoid putting the optosensor into water deeper than a few centimetres, otherwise water pressure could force water into small unsealed openings.

Note that the sensor must be shielded from external lighting and so only respond to the l.e.d.

Should a negative sign (−) be shown on the l.c.d. following the W character, recalibrate using switches S1 and S2. This situation is likely if the minimum coil frequency falls below that set, as caused by any frequency shift due to temperature changes.

Finally

It is expected that prop monitoring will be carried out under controlled conditions, in a bath tub or fish tank (occupants evicted first in both instances!), for example. In this case, the whole assembly can be tailored to suit those conditions, constructing a suitable framework to ensure that the boat maintains position against the solenoid, and the optosensor stays aligned with the propeller.

The power developed by a wheeled model's motor can also be assessed by this design. The principle could also be modified for use with model helicopters, using the assembly vertically instead of horizontally. Resist the temptation to use the design with a model submarine in descent mode!

Resources

Software for the PIC, including source code files, can be downloaded *free* from the *EPE* Downloads site, accessible via the home page at **www.epemag.co.uk**. It is held in the PICs folder. Download all the files within that folder.

This month's *Shoptalk* provides information about obtaining pre-programmed PICs.

The PIC program source code (ASM) was written using *EPE toolkit TK3* software (also available via the Downloads site) and a variant of the TASM dialect. It may be translated to MPASM via TK3 if preferred. The run-time assembly is supplied as an MPASM HEX file, which has PIC configurations embedded in it. If you wish to program the PIC yourself, simply load this HEX file into the PIC using your own PIC programming software and hardware. □

Circuit Surgery

Ian Bell

In response to a reader's question, our "consultant surgeon" amplifies gain and impedance calculations

THIS month we get back to basics with a question on transistor amplifier circuits posted on the *EPE Chat Zone* by regular contributor Alan Jones. He says,

For a simple, single transistor amplifier, gain equals value of collector resistor divided by value of emitter resistor. If the emitter resistor is bypassed by an electrolytic capacitor, gain is increased as the emitter resistance is reduced to something like 25 ohms. This is a rough approximation but close enough for most purposes.

My question: does a similar calculation apply to a simple FET circuit (or a valve circuit for that matter) and what is the impedance value equivalent to "emitter resistance" when a bypass capacitor is used?

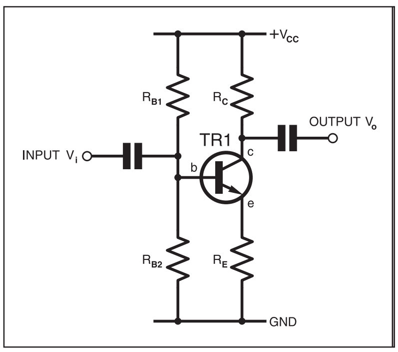


Fig.1. Basic bipolar transistor amplifier circuit

Starting with the bipolar transistor circuit, which is shown in Fig.1, we will look first at the emitter resistor and its importance in single transistor amplifiers. We will also show how we get the formula for gain and where the value of 25 comes from. Armed with this understanding we will move on next month to look at the FET version of the circuit.

The circuit in Fig.1 is a classic transistor amplifier circuit, which has a voltage gain of R_C/R_E as mentioned in the question. The key thing here is that the gain of the circuit depends on the resistor values and not on the gain of the transistor. This is similar to an op.amp amplifier where the feedback and input resistors set the gain. In fact the situation is the same – it is the application of negative feedback in both an op.amp amplifier and this transistor circuit that allows the gain to be set by the resistor values alone.

Negative Feedback

The emitter resistor produces negative feedback as follows. Imagine the base voltage increases, increasing the base-emitter voltage V_{BE}, this will tend to cause more collector current, I_C, and hence more emitter current, I_E, to flow. A larger emitter current causes a greater voltage drop across R_E, which tends to reduce V_{BE} and hence reduces I_E. So an increase in current in the transistor due to increased base voltage is opposed by the voltage across R_E – negative feedback occurs.

For a given value of R_C the larger the value of R_E the more feedback is applied and the lower the gain – voltage gain is inversely proportional to R_E as indicated by the formula. The voltage gain increases if R_C is increased because the output from the transistor is fundamentally a current, the collector current signal, i_C, which is converted to the output voltage by R_C. The output voltage signal is $R_C i_C$, so the voltage gain is proportional to R_C as indicated by the formula.

One thing we are doing when we use negative feedback with an op.amp or a transistor circuit is trading off high gain for other desirable properties. For example the transistor may have a gain of 100, 200, or more, but the circuit may be designed for a gain of 10. This is not a waste because we get a circuit with more reproducible gain, lower distortion, higher input resistance and lower output resistance.

The fact that we get reproducible gain, that is if we build, say, ten copies of the circuit they all have the same gain, is very important. Individual transistors have widely varying gains; you just need to check the datasheets to confirm this. The manufacturers give you a typical gain

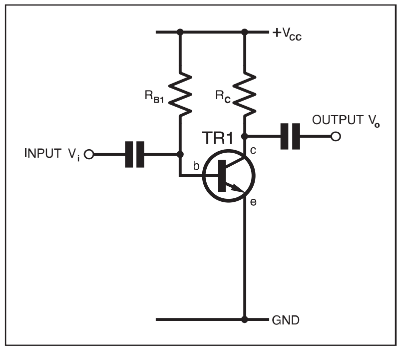


Fig.2. Simple transistor amplifier circuit

value on the datasheet, but also minimum and maximum. A transistor with a typical gain of 100 might have a minimum of 50 and maximum of 250 or more. So if your circuit depended on the transistor gain it could it show a five fold variation between individual copies and provide obviously unpredictable performance. Transistor gain varies with temperature and other factors too so the performance of such a circuit will vary over time.

And it is even worse than that. The variation in transistor gain means that without feedback it is very difficult to bias the transistor in a stable and predictable way. Fig.2 shows a circuit that we might use. We could try the following to set up bias. First we choose the collector current we want with no signal present (the bias current). To do this we could look on the datasheet to find the collector current which gives the highest gain (yes, transistor gain varies with I_C). Let's say we choose 1mA for I_C bias. Then we look up the typical current gain of the transistor (known as β or h_{fe}) – let's assume it is 100.

To get 1mA of collector current we need 1mA/100 or 10µA of base current. The base current is set by R_{B1}. The voltage drop across R_{B1} is $V_{CC} - V_{BE}$. If we have a supply of 9V and make a reasonable assumption that V_{BE} will be around 0·6V the value or R_{B1} should be

(9–0·6)/10µA (Ohms law), which is 840kΩ. We chose R_C so that with no signal present the voltage at the collector is half way between supply and ground. Doing so gives us the largest potential output voltage swing from the amplifier. So we need R_C to drop 4·5V with 1mA through it – a value of 4·5kΩ.

Collector Current

Now we have our circuit and all seems to be fine, except when we remember that the gain of the transistor may be 50 or 200 rather than 100. A gain of 50 will shift the collector current down to 0·5mA and the no-signal voltage at the collector up to 6·75V, reducing the maximum output swing from about 4·5V to 2·25V. A transistor gain of 200 is worse as this would give a collector current of 2mA causing R_C to drop all 9V of the supply. The collector voltage would be just above ground and circuit would not be usable as an amplifier.

We bring in R_E with its negative feedback, and the biasing arrangement already shown in Fig.1 to overcome this problem. To bias this circuit we start in a similar way, choosing I_C (we can use the 1mA example again), we can also set R_C to give half the supply voltage at the collector with no signal present, so R_C can be 4·5kΩ again. Let's assume we want a gain of 4·5 for the circuit, so using gain = R_C/R_E gives us 1kΩ for R_E.

This gives us 1V at the emitter with no signal present. If V_E is 1V then V_B will be about 1·6V assuming that V_{BE} is about 0·6V. The biasing in Fig.1 is different from that in the poor circuit of Fig.2. Here we set the base voltage (1·6V in our case) rather than the base current. Another difference with this circuit is that the minimum output voltage is the emitter bias voltage (1V here) rather than close to ground, but this is a small price to pay for the increased stability.

Two resistors are used as a potential divider to provide the voltage we want. We choose these resistors such that a least 10 times the required base current is following through them. That way variation in base current will not change the bias voltage significantly. Given a base current of around 10µA (as before) we need about 100µA or more in the potential divider. Thus its total resistance should be less than 90kΩ. The base voltage is given by $V_{CC}R_{B2}/(R_{B1}+R_{B2})$. If we choose R_{B2} we can find R_{B1} using $R_{B1}=R_{B2}(V_{CC}-V_B)/V_B$. For example if we select 10kΩ for R_{B2} then R_{B1} needs to be about 46kΩ. The total is less than 90kΩ as required.

Variation of V_{BE}

The value of V_{BE} will vary with individual transistors and temperature, but the variation is small (should be less than 0·1V) and will not upset the circuit in the same way as transistor gain variation upsets the circuit in Fig.2. Note that in our calculation of the bias conditions for Fig.1 we have not used the transistor gain, except for checking that the current in the potential divider is well above the base current.

A question that remains is how do we know that gain of Fig.1 is R_C/R_E? Earlier we argued that increasing R_C increased the gain and increasing R_E reduced it, but this only gives a feel for what is going on, not an exact formula. To analyze transistor circuits in more detail we can use what are known as *equivalent circuit models*. The equivalent circuits consist of simple components such as voltage sources, current sources and resistors which together approximately mimic the action of the transistor. Once a transistor has been replaced by its equivalent circuit the whole circuit is more easily analyzed using basic circuit theory.

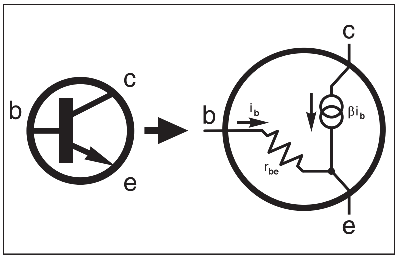


Fig.3. Simple equivalent circuit for a bipolar transistor

There are a large variety of such models for different situations and with varying complexities. The more complex the model the more accurate it is likely to be, but calculations will be more difficult and time consuming. Fig.3 shows one of the simplest equivalent circuits for the bipolar transistor. It comprises a current source which produces the collector current and a base-emitter resistance, r_{be}, through which the base input current flows. The value of the current source is βi_b, that is the transistor's current gain times the base current.

Ignore D.C. Voltages

We can also use another major trick to simplify our circuit analysis – we completely ignore all d.c. voltages and currents and only analyze the signals. We assume that our signal is so small that it does not change conditions in the circuit. If the circuit is linear (which is what we want from an amplifier) then we can ignore the bias and still get the right answer. So before analyzing the circuit we set all the d.c. voltages to zero. In practice this typically means replacing the power supply with a short circuit. This may seem weird at first, but it works.

The circuit of Fig.4 shows Fig.1 treated in this way. The transistor has been replaced by the circuit from Fig.3. and the supply is short circuited. We can simplify things further still as indicated by the grey components which we can also remove. As we are dealing with the signal alone we do not have to worry about d.c. blocking by the coupling capacitors. If we assume our signal is not at the extremes of the circuit's frequency range we can assume that the coupling capacitors have very low impedance and can replace them with short circuits (but we have to keep the capacitors to analyze frequency response).

If we assume the signal source (V_i) has a very low output impedance it will not be loaded by the circuit, which is the only effect that R_{B1} and R_{B2} might have under

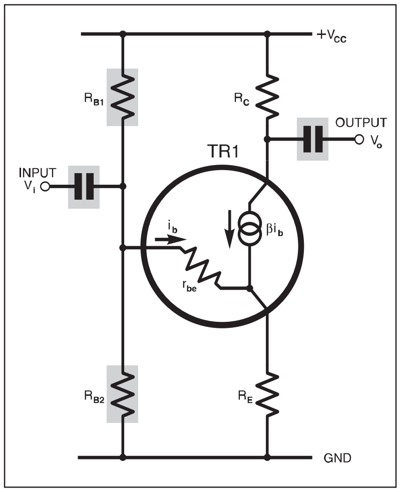


Fig.4. Simplified "signal only" equivalent circuit for analysis

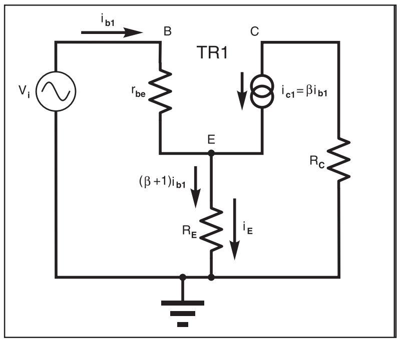


Fig.5. Redrawn simplified version of Fig.4

our simplified "signal only" view of the circuit. Therefore these can also be removed. Having done all this we can redraw the circuit as shown in Fig.5, with input on the left and the output on the right.

In Fig.5 we have also labeled the currents and voltages. i_{b1} flows through r_{be} and then R_E. The collector current, βi_{b1} flows through R_C and R_E. So the total current in R_E is the sum of both of these, that is $i_{b1} + \beta i_{b1}$ or $(1 + \beta)i_{b1}$. The voltage drop across R_E is R_E times the current through it, that is $(1 + \beta)i_{b1}R_E$. The voltage drop across r_{be} is $i_{b1}r_{be}$. The voltage across R_C is the collector current times R_C, which is $\beta i_{b1}R_C$, which is also equal to the output voltage. The input voltage, V_i is equal to the voltage dropped across R_E plus the voltage dropped across r_{be}, so this is $i_{b1}r_{be} + (1 + \beta)i_{b1}R_E$. The voltage gain of the circuit is the output signal voltage divided by the input signal voltage, so the gain is

$$\frac{\beta i_{b1}R_C}{i_{b1}r_{be} + (1+\beta)i_{b1}R_E} = \frac{\beta R_C}{r_{be} + (1+\beta)R_E}$$

This isn't quite the R_C/R_E we are looking for, but actually we are almost there. The i_{b1}s all cancel, as shown, and then we can think about the relative importance of each part of the formula. Transistor gains are large, typically 100 or more, so β is much greater than 1, so $(1 + \beta)$ is not much different from β, particularly given that we

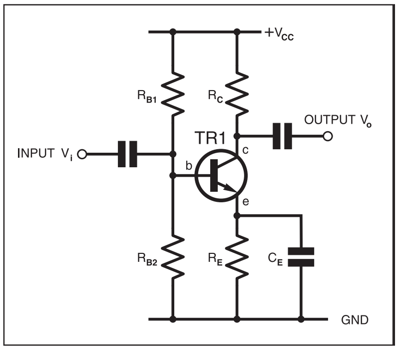


Fig.6. Bypassing R_E for more gain but with bias stability

know that β varies so much from transistor to transistor the difference between 100 and 101 is not significant. We can replace $(1 + \beta)$ in the equation with just β. The value of r_{be} is typically a few kΩ, as is R_E, so looking at the bottom half of the equation we have $r_{be} + \beta R_E$. The βR_E bit will typically be 100 times bigger than r_{be} so we can remove r_{be} without introducing too much error. Thus the equation reduces to

$$\frac{\beta R_C}{\beta R_E}$$

And hey presto! the βs cancel out and we get our R_C/R_E. If we have the following typical values R_C=4·5kΩ, R_E=1kΩ, r_{be}=2·5kΩ, β=100, then the full formula gives us a value of gain of 4·35 and R_C/R_E is 4·5. This is about a 3% error – less than the tolerance of 5% resistors.

Bias Stability

The gain of the Fig.1 may be too low for some applications, but if we remove or greatly reduce R_E we loose our bias stability. The solution is to bypass R_E with a

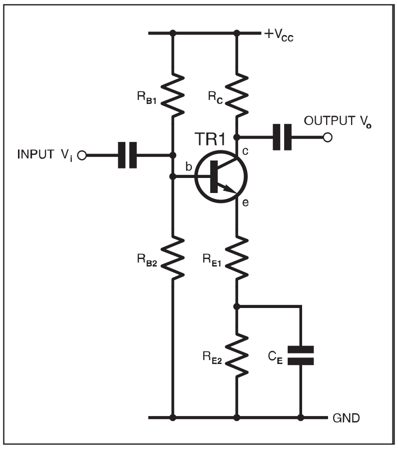


Fig.7. Partial bypassing of R_E for better controlled gain

capacitor as shown in Fig.6. At d.c. the capacitor is an open circuit and the circuit of Fig.6 is effectively the same as Fig.1 – we get our full bias stabilization. Fig.7 is a combination of the two approaches R_{E1} and R_{E2} in series provide full bias stabilization, but at a.c. R_{E2} is effectively shorted out by C_E so the a.c. gain is R_C/R_{E1} as long as R_{E1} is not too small.

For a.c. the effective value of R_E in Fig.6 is the parallel combination of R_E itself with the impedance of C_E. For large capacitors (e.g. if we use an electrolytic as suggested) and reasonably high frequencies (e.g. in the audio range and above) the impedance of C_E is much smaller than the R_E resistor so we can take the effective value of R_E simply as the impedance of C_E. This is a small value so using R_C/R_E indicates the gain should be large for the circuit in Fig.6. Indeed the gain is large, but unfortunately we cannot use this formula in this situation as the approximations we made to obtain it means it no longer holds true.

Numerical Examples

Some numerical examples will show why our simple formula no longer applies. If C_E is 10µF, at 1kHz it has an impedance of around 16Ω. This means that the approximation we made above that r_{be} is much smaller than β_{RE} is no longer valid (r_{be} is about 2·5kΩ and β_{RE} is about 1·6kΩ (for β=100) and we should use the full formula. For C_E=100µF at 10kHz, β_{RE} is about 16Ω so r_{be} completely dominates the bottom half of our full formula and we can ignore the β_{RE} part. This gives us a new approximate formula, which becomes $R_C/25$ if we use typical values for β and r_{be}:

$$\frac{\beta R_C}{r_{be}} \approx \frac{100 R_C}{2500} = \frac{R_C}{25}$$

This is where the 25 in the question comes from. Another way of looking at it is that the transistor has an internal emitter resistance, r_e, of 25Ω. In Fig.6 at high frequencies the capacitor is effectively a short circuit so the only resistance in the emitter circuit is that of the transistor itself, and we can put R_E=25 in the R_C/R_E formula (R_C/r_e really). Actually the value of r_e varies with emitter bias current; r_e is about $25/I_E$ with I_E in mA at room temperature (so we get 25Ω with 1mA). The base-emitter resistance we used in the transistor model and full formula above and r_e are related by $r_{be}=\beta r_{e}$.

As you can see there is a lot behind the simple statements about the bipolar transistor version of this circuit made in the question. Useful circuit formulae are quite often approximations which only apply under certain conditions, having some idea of what these conditions are means we can use them with more confidence.

Next month: The FET version

Ingenuity Unlimited

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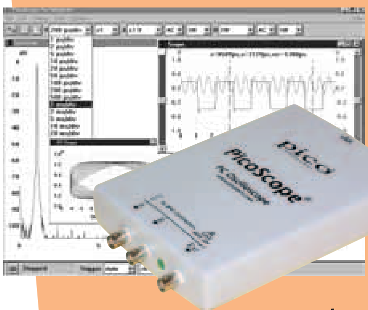

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Multitone Generator – *Getting in Shape*

SOMETIMES you need a waveform having a particular shape, frequency, or amplitude that is not provided by your signal generator, or maybe you just do not own a sig. gen. If you don't mind spending a bit of time experimenting with component values, the Multitone Generator circuit described here might just give you the waveform that is needed.

The circuit diagram shown in Fig.1 requires a bi-polar power supply, which is provided by two 9V batteries wired in series; their positive/negative junction being used as the "ground" or common 0V line. Operational amplifier (op.amp) IC1 is used as a sensitive voltage comparator, whose trip level – the value at which the output changes state – is determined by potentiometer VR1.

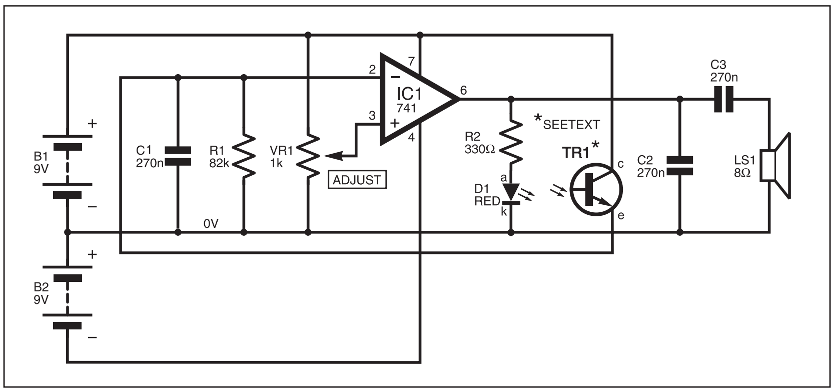

Fig.1. Circuit diagram for the Multitone Generator

The combined resistance of resistor R1 in series of phototransistor TR1 provides the feedback divider for IC1's inverting (–) input. Since TR1's dark resistance – when there is no light – is very high, very little voltage appears across resistor R1; therefore, IC1's output (pin 6) will normally be high.

When power is first turned on, IC1 goes high, causing the l.e.d. D1 to light. However, the instant it glows it shines on phototransistor TR1, causing a decrease in TR1's collector/emitter resistance, which also causes a large voltage drop across resistor R1. The comparator immediately switches to a low output, thereby turning l.e.d. D1 off, which restores TR1's dark resistance. This increase in TR1's resistance causes the cycle to repeat, thereby producing an oscillating output voltage.

Logically, the circuit should "lock-up" because the l.e.d. and phototransistor would be competing with each other for control of the circuit, and IC1 would get stuck in some equilibrium state. However, capacitor C2 prevents this from happening by keeping l.e.d. D1 lit slightly longer than the normal turn-off time. (Capacitor C1 also helps avoid lock-up, but its use is not critical and it can be eliminated.)

The output frequency can be changed by varying the capacitor values, but keep in mind that making their values too small will defeat their primary purpose, which is avoiding circuit lock-up. The frequency, amplitude and the shape of the waveform is determined by the setting of VR1.

The only critical part of the assembly is the positioning of l.e.d. D1 and phototransistor TR1. They must be facing each other, close and shielded from ambient light – perhaps by placing them inside a small cardboard or opaque plastic tube.

Alternatively, you could try substituting an opto-isolator for D1 and TR1. However, bear in mind that the spacing between l.e.d. D1 and phototransistor TR1 provides some control over the output waveform; an opto-isolator would eliminate that degree of control.

Craig Kendrick Sellen, Carbondale, USA

Electret Mic Tester – *Phantom Addition*

MY test-bench audio amplifier contains a power supply, selectable RIAA preamp (built from a kit), power amplifier (p.a.) to an *EPE* design, a speaker (of nostalgic make but able to handle the power and still going strong!) and enough fresh air to add more. Having some surplus electret microphones to test, it was decided to add switchable phantom power to the specification recommended by Raymond Haigh (*Audio System – Communications* (Aug '05).

Referring to Fig.2, a separate line is taken from the internal 12V supply, so as to minimise coupling between the p.a. and the low-power add-on circuit. The voltage stabiliser around TR1 relies on Zener diode D1 (BZX85C5V1) with through-current arranged to give close to the 5·1V voltage drop by selection of the appropriate value for R1. TR1 base-emitter junction drops 0·6V to give the recommended 4·5V at its emitter. This 4·5V rail is decoupled by C1 and resistor R2 feeds any electret, as required, when switch S1 is closed.

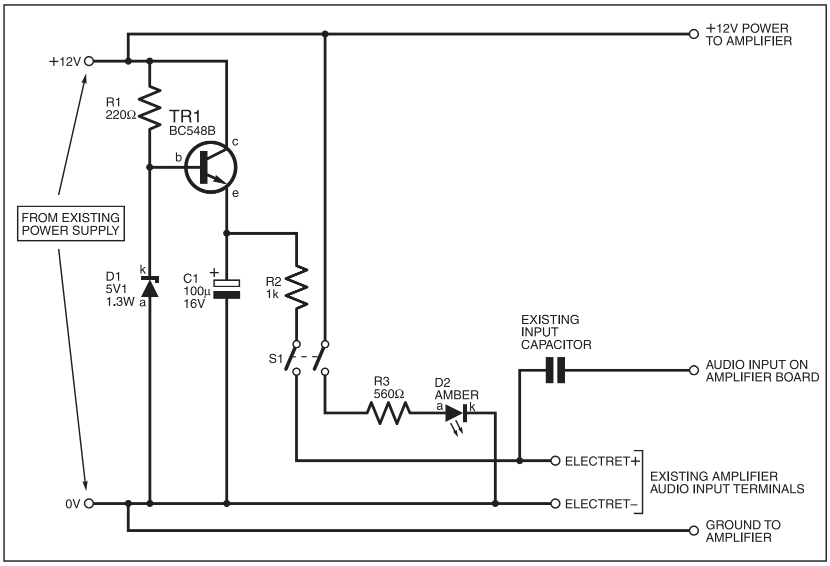

Fig.2. Circuit diagram for Electret Microphone Tester

The power is fed to the same point (in the complete unit) from which the audio input is taken to the internal electronics. A high-voltage capacitor is already in place, protecting the internal electronics from any standing direct current present on an input device.

Unfortunately, this same protection cannot be afforded to the phantom power generator as this latter is itself a d.c. supply. However, this phantom power is blocked by the existing capacitor and therefore does not harm the rest of the internal electronics. Some input devices (such as dynamic microphones or magnetic pick-ups) will not be "impressed" by 4·5V being "impressed" (!) upon them, but the worst-case short-circuit current is limited to 4·5mA by R2. The other pole of S1 switches an l.e.d. indicator (separate circuit) as a warning not to connect such devices while phantom power is applied!

Godfrey Manning G4GLM, Edgware, Middx

SHOP TALK
with David Barrington

Vehicle Frost Box Mk2

All parts listed for the *Vehicle Frost Box Mk2* should be readily available from our components advertisers. If, as stated in the article, any readers experience problems with "spikes" (interference) from ignition circuits etc., the LM2940 regulator is a more robust device and could be substituted for the 78L05.

For those readers unable to program their own PICs, an 8-pin ready-programmed PIC12F675 can be purchased from **Magenta Electronics** ***(☎ 01283 565435*** or ***www.magenta2000.co.uk)*** for the sum of £4.90 each (overseas add £1 p&p). The software, including source codes, is available for *free* download via the Downloads link on our UK website at **www.epemag.co.uk**.

The printed circuit board is available from the *EPE PCB Service*, code 543 (see page 891). "Bullet" connectors should, of course, be stocked by most motor spares shops.

Propeller Monitor

The Sharp IS436 Schmitt trigger opto-sensor used in the *Propeller Monitor* project was purchased (*credit card only*) from **RS Components** (***☎ 01536 444079 or rswww.com)***, code 197-025. They also supplied the compression spring, code 821-380.

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Before undertaking the construction of the *Solid-State Valve Power Supply* project, we would first remind would-be constructors that the high voltage HT generated by this circuit is still dangerous and great care should be exercised at all times whenever powering the unit.

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Teach-In 2006 Part1 (Nov '05)

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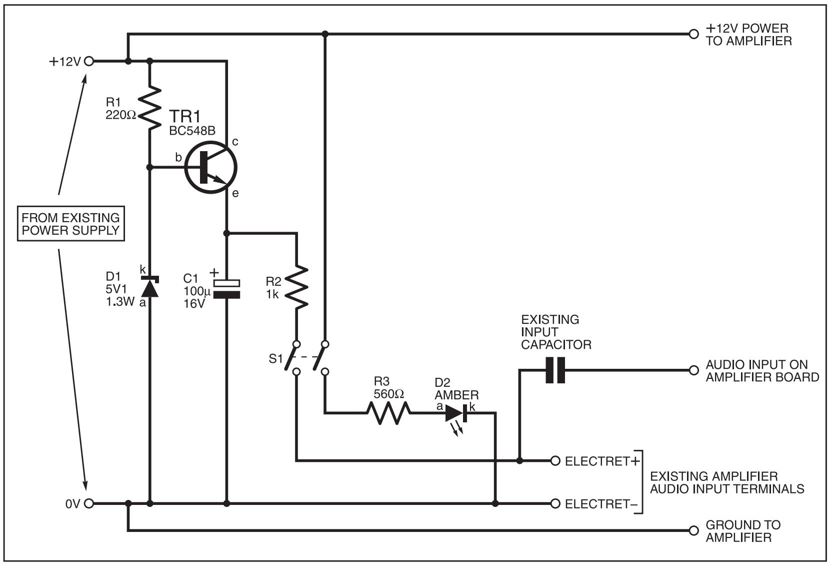

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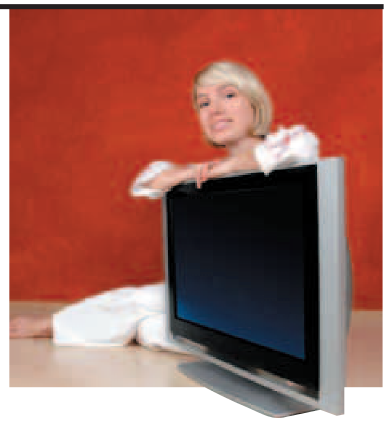
Viewing the Future



Barry Fox

New viewing techniques are revealed at this year's IFA show, as Barry Fox reports

Berlin's giant *International Funkausstellung* exhibition is staged every two years and has become the traditional European launch-pad for all new home entertainment technology.

This year the huge exhibition site was awash with flat panel screens, demonstrations of digital HDTV and promises of HD recording on blue laser disc. It was hard to find a good old cathode ray tube and analogue tuner. Clever technology risks getting lost in the jungle of giant screens. But we spotted several pointers to the future.

Many have tried to deliver real 3D TV without special glasses, and with everyone in the room getting the same effect – and many have failed. However, German company Grundig (now controlled by Alba of the UK and Beko of Turkey) scored *oohs* and *ahs* from a large roomful of sceptics with a working demonstration of no-spectacle 3D from an ordinary l.c.d. screen.

3D Techniques

Old 3D systems delivered a left perspective image to the left eye, and right to the right. The screen displays both images at the same time and the viewer has to wear coloured or polarised spectacles to stop the left eye seeing the right image, and vice versa.

Lenticular systems slice the left and right images into narrow vertical stripes, interleaves them and puts small prisms over the picture to steer the left and right image stripes into the left and right eyes. Simple versions, as used for 3D postcards, rely on the viewer being stationary, with eyes directly in front of the picture. Modern versions, as pioneered by Sharp, either require the viewer to sit tight in a sweet spot or rely on a camera to track the position of the viewer's head and adjust the screen display to match.

Grundig has been working with German companies X3D Technologies and 3D Image Processing, and Cobalt Entertainment of Hollywood, on a system which splits the image into eight perspectives instead of two. This gives a 3D effect over a wide viewing area, and so avoids the need to track the head position.

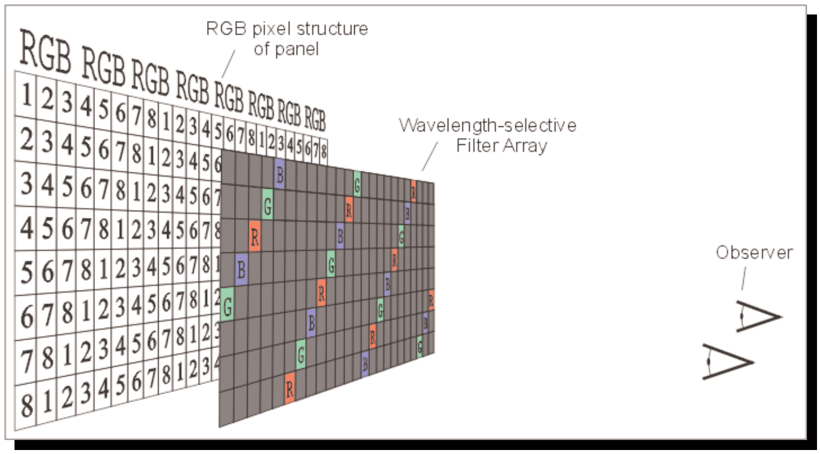


Fig.1. The X3D system puts a Wavelength-Selective Filter Array in front of the panel of a flat display. The filter transmits or occludes certain sub-pixels on the panel, depending on the viewing position of the observers eyes. The 3D image slices are angled to match the filter structure.

A pair of high definition TV cameras, spaced slightly wider apart than human eyes, captures left and right views with exaggerated perspective. Image processing software compares these two images and generates eight images which smoothly range from extreme left view to extreme right.

The eight perspective views are simultaneously displayed on a conventional plasma or l.c.d. screen, as interleaved narrow slices. A filter panel, fixed to the front of the screen, makes the different views visible from different angles – see Fig.1. From anywhere in the room, a viewer's left and right eyes are always seeing two different views, one with a leftish perspective and the other a more right perspective.

Selective Filtering

As Grundig proved in Berlin, by inviting the audience in a large room to move around, this gives 3D over a 120 degree viewing angle. Instead of using lenticular glass prisms to steer the light, Grundig uses a selective colour filter developed and patented by X3D. The filter creates tight light pathways for the red, green and blue pixels of the screen, as in Fig.1.

The eight perspectives are converted into digital code using the new MPEG-4 system, now being adopted as the standard for HDTV broadcasting. MPEG-4 can cram eight digital TV signals into the bitspace normally needed for one of today's MPEG-2 digital TVs, so one TV channel can deliver all eight views.

After an embarrassing false start, when the law of cussedness left Grundig playing a fanfare and unveiling a screen displaying only a drunken double image, an assembled crowd of hundreds saw live TV images stand out from the screen. Picture definition and brightness are somewhat degraded by the filter, but using HD screens should help redress the quality balance.

"This is not just fun and games", says Thomas Haida, Grundig's Director of Product Development. "We will have a prototype product by the end of 2006 and 3DTVs and DVD players on the market in 2007. Hollywood is desperately waiting. We hope to run live tests during the FIFA World Cup football in Germany next year.

And you won't get sore heads and feel dizzy like you do after a few minutes watching 3D with spectacles".

Split Channel Viewing

Meanwhile Sharp has modified its own 3D technology to display two completely different pictures depending on which end of the sofa you are sitting. So one viewer watches football while the other watches tennis. Another variation of the same system makes the screens of laptops, PDAs or cash machine ATMs show useful data only to the front; anyone trying to sneak a look from the side or next seat sees only a screen saver.

French electronics giant Thomson wants to cut the cellphone industry out of Mobile TV. Thomson's new pocket digital TV, due in January'06, works with the existing DVB-T broadcast system. There is no need for the viewer to pay for the cellphone connection needed by the new Mobile TV systems like DVB-H.

Thomson's 11cm l.c.d. screen has two stubby aerials, arranged in a V-shape, feeding two tuners which continually analyse the thousands of separate OFDM (orthogonal frequency division multiplex) radio carrier signals used for DVB-T, and pick the best. The receiver gives steady pictures inside a house or on the move.

Battery-Powered Projection

Toshiba will soon start selling the first battery-powered video projector that is small enough to fit in a big pocket – it could work on the move with Thomson's TV.

The new projector uses one of Texas Instruments' DLP digital micromirror chips to form the video image. But whereas existing DLP projectors use a bright white lamp and a rapidly rotating wheel with red, green and blue filters to add colour to the picture, Toshiba's new system uses red, green and blue l.e.d.s. There is no need for a colour wheel and no need for a cooling fan either, because the l.e.d.s generate very little waste heat. The unit can be much smaller and lighter too; 136mm x 39mm x 100mm in size and weighing 565gm.

The l.e.d.s are claimed to last for 10,000 hours and can be switched on and off at the flick of a switch, and without the long warm-up and cool-down times needed to stop conventional and costly projector lamps failing.

Toshiba's portable has a USB socket on the side as well as conventional video connections. So it can be whisked out, plugged into a TV, DVD player, laptop, game console, camera or phone, and have pictures on screen in two seconds.

Resolution is SVGA, with 800 x 600 pixels. The l.e.d.s generate 300 lumens, with 1500:1 contrast, which is enough light for a projected picture the size of a domestic TV screen. The pocket projector goes on sale before the end of this year. It comes in a carrier bag with a fold-up screen, and the rechargeable battery runs for two hours.

Just the Trick

Pulling the book-sized gadget out of a small bag, like a rabbit out of a hat, Gerd Holl, Manager of Toshiba's Projection and Display Technology group, predicted that it would let projection "break out of the mould and enjoy unrestricted freedom and mobility".

Showing a picture of a tent on a camp site Holl suggested: "With a portable DVD player and our new projector you and your girlfriend can watch movies in the fresh air. Two hours battery life is enough for a full length film. Phones can now download movie material, and you can screen that too by using the USB connection".

Toshiba's announcement could well signal a whole new trend in video projection. A Korean inventor has just filed patents in the US for a DLP projector that uses a digital micromirror and three lasers, emitting very powerful red, green and blue light. The pictures will be brighter but power consumption will be higher, making battery operation unlikely.

Miniature iPod Hard Drives

Hitachi will soon start supplying a new miniature hard drive for use in iPods, MP3 players and cellphones, cameras and laptops. The disc has Extra Sensory Protection. A finely balanced quartet of tiny piezo sensors senses any tilt from side to side. The only time there is no tilt to sense is when the drive is in free fall with zero gravity i.e. when the device is being dropped. So when zero gravity is sensed the hard drive is disabled to park and protect the heads. ESP works fast enough to protect for any drop over 10cm.

The same system can be used to detect motion, says Hitachi. So the owner of a PDA may soon be able to write text by waving it in the air in the shape of letters.

Pacing the Beat

The Fraunhofer Institute, inventor of MP3, always puts on an impressive show of new research projects at IFA. The latest Fraunhofer software disassembles a music recording and strips out just the rhythmic drum beats. It then rebuilds the drum sounds with completely different percussion instruments, for instance replacing bass kick drum with a cymbal or snare. The system can be used for programming electronic musical instruments, DJ remixes, and home studio recording. Musicians can sample a famous pop recording and make it sound different.

Fraunhofer says it is now adapting the system to re-assemble whole songs at different tempos, to help over-weight joggers with weak hearts keep pace with their favourite music at safer tempos.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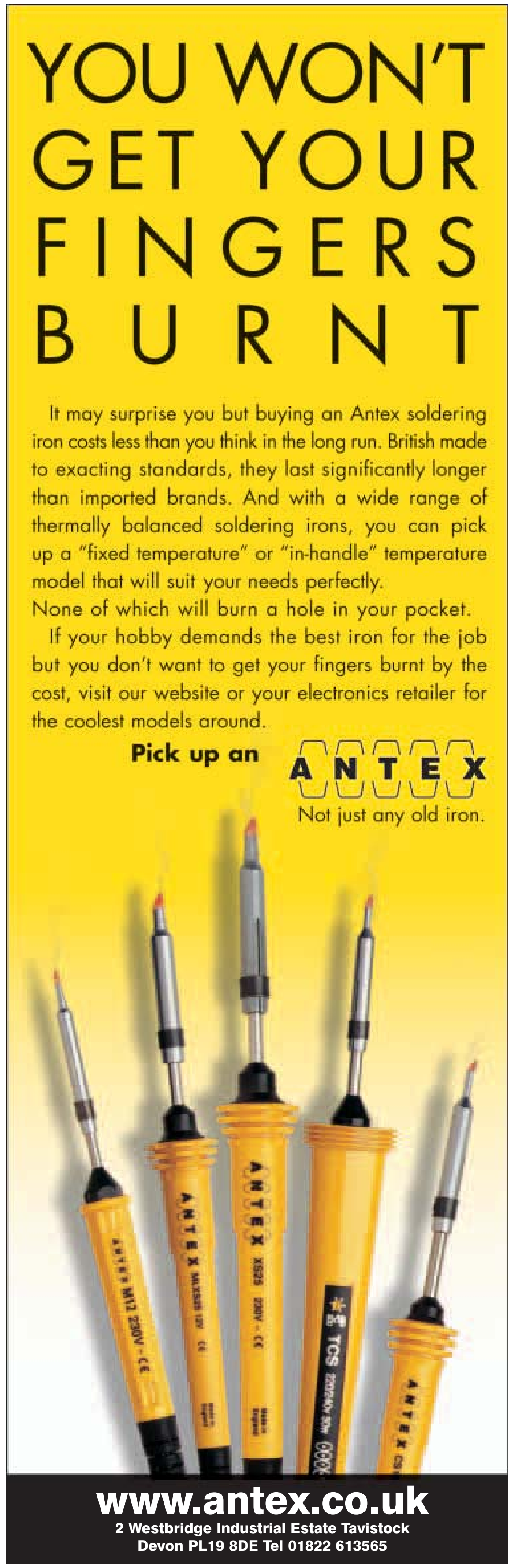
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Net Work

Alan Winstanley

Free Virus Check!

This month the Internet column revisits the subject of anti-virus (A/V) protection. Computer viruses come in many shapes and sizes. For example, the infamous Chernobyl/CIH Virus of 2002 would attack Windows 95/98 machines and try to wreck the hard drive and BIOS. It caused considerable damage to innocent or unsuspecting users e.g. a charity's IT systems. The author's computers are equipped with twin BIOS chips, just in case.

Some viruses classed as "worms" replicate faster than bacteria snacking on a Petri dish, and keep reproducing themselves until machines or even entire networks grind to a halt. A "Trojan Horse" virus may enter a system as part of an innocent-looking file (e.g. an electronic greeting card or an upgrade), and then reside on a network, perhaps building a back door for hackers or recording your keystrokes.

A compromised machine can be turned into a "zombie", and hackers can then direct an army of zombies against a target in a Distributed Denial of Service (DDoS) attack. The avalanche of incoming traffic created by hundreds of zombie machines cripples the target.

Services such as P2P (peer-to-peer file sharing sites) or IM (Instant Messaging) systems including ICQ and AIM are prone to virus attacks. Even the simple act of visiting some web pages can cause a malicious script or "exploit" to launch that will attack vulnerabilities in your computer. Spammed emails might link to web pages containing code that drops a trojan onto your machine.

Unprotected Consequences

The consequences of a brand new unprotected computer becoming infected on the Internet were demonstrated by Tom Liston in his astonishing analysis published on the respected SANS computer security and research web site (**www.sans.org**) last year; the document on **http://isc.sans.org/diary.php?date=2004-07-23** describes under "Following The Bouncing Malware [Parts 1-4]" how a single visit to an innocent looking web site triggered a chain of events resulting in the Trojan *Win32/TrojanDownloader.Rameh.C* and more besides being planted onto a machine.

The description is in several parts (posted over several months – they take some finding!) and will be of interest to web coders and more advanced Internet users – but even if you don't understand the technical code, you will certainly be horrified by Liston's summary of events. It also demonstrates the consequences of code *obfuscation* – disguising malware commands with non human-recognisable characters or gibberish.

Having a current anti-virus system running at all times is a prerequisite for all computer users. After quite a few years of using Symantec Anti Virus with reasonable results, upgrading or renewing subscriptions annually by inertia, the writer decided it was high time to investigate some alternatives. Surprisingly, a free downloadable package turned out to be more effective in some ways than the commercial paid-for product that it was being pitted against.

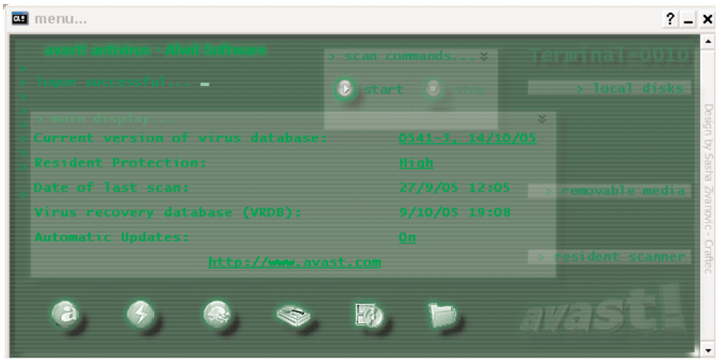
A Bohemian Rhapsody

During a computer upgrade, a computer specialist suggested Avast Anti Virus (**www.avast.com**), produced by ALWIL Software in the Czech Republic. (Do try the Radio Prague English language portal site at **http://radio.cz/en/**). The company's name may be unfamiliar and some users accustomed to using flashy, packaged, branded Western products such as Symantec or McAfee may need a leap of faith before installing a program hailing from Prague instead of Cupertino, California.

I happily installed ALWIL Avast, and a 9MB download later I was in business with a 60 day demo, scanning a 120GB drive that was being moved onto a new machine. The shock was that during tests on the author's system, Avast found a number of infected files that Symantec 2005 had overlooked. ALWIL is proud of its awards for a 100% detection rate.

When you open the program, Avast is very different in appearance from any other commercial A/V program. You can change its look using alternative attractive skins, downloadable from the web. A command-line scanner is also included.

A two minute tour of this deceptively powerful program reveals amongst other things the Virus Chest, the equivalent of a quarantine area, and the iAVS button that updates the database. In practice the database frequently updates itself (a pop-up displays and a voice clip plays to confirm this), sometimes updating several times a day. This appears to be far better than the product's leading competitor and on the author's connection the check takes as little as four seconds.



One of many different skins available for you to customise the software

The controls are simple. Select a "Scan area" – choose local disk(s) in their entirety, and/or removable drives, or select individual files and folders instead. Choose how thorough the scan should be. A "Play" button sets the scan under way and a spinning letter "a" icon in the system tray confirms activity. Also visible is a letter "i" icon, which relates to Avast's Virus Recovery Database. The theory is that if in the worst case a virus does somehow damage a file, Avast's database can repair the damage by cross-referring up to previous versions. The VRDB tool creates the database during slack moments. I particularly liked the anti-virus scanning screen saver too.

The Resident scanner runs a number of "provider" modules that guard web, email, P2P services and more. After several months of use on a number of home machines, ALWIL Avast has proved itself to be a highly capable product that is easy to use and frequently updates itself. The free package means there is no reason not to use this anti virus system at home whilst the paid-for version has a number of additional features. Give it a try. Another free package to consider is AVG Anti Virus from **www.grisoft.com** which has many followers.

You can email the writer at **alan@epemag.demon.co.uk**

Constructional Project

Solid-State Hammond

Thomas Scarborough

Add moving spatial ambience to your stereo recordings

STEREO recordings sometimes tend to be remarkably "flat" or one-dimensional. Normally these are recorded in a studio, so that musicians and singers remain relatively stationary in relation to the microphones. When the music is played back, one receives a fairly static "sound picture" – despite it being stereo.

Contrast this with reality – particularly in a smaller setting – where a singer will turn this way and that to the audience, a violinist might twist while playing, or a drummer on bongo drums might move between two or three sets of drums. In short, there is a good deal of motion in a real life "sound picture" that might not find its way into a stereo recording.

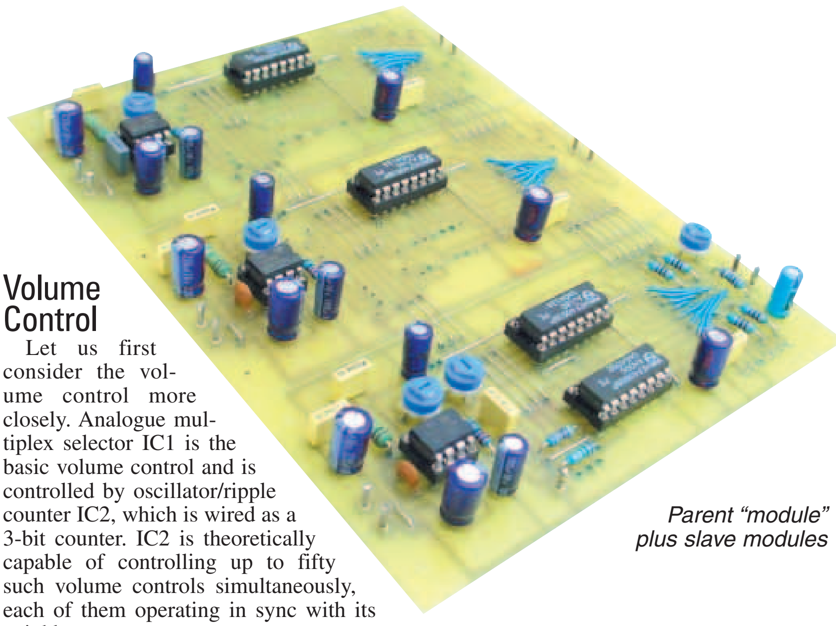
One of the accomplishments of the present project is to "explode" stereo sound, and to restore to it its life and "motion". There is no doubt, when the Solid-State Hammond system is added to the stereo system, that the sound picture has changed and come alive. With some stereo recordings the effect is really impressive.

The "Hammond" designation is described in more detail below. This has to do with the project's ability to shift sounds and tones around a room, and therefore, to a limited extent, to simulate the famous Hammond organ effect.

In Concept

On the surface of it, the circuit diagram for the Solid-State Hammond, as shown in Fig.1, would not seem to accomplish much – but this is deceptive. IC3 is a 2W r.m.s. amplifier, the volume of which continually rises and falls (this may be replaced with almost any amplifier of one's choosing – see later). Together IC1 and IC2 represent an automatic volume control, which cycles endlessly through high and low volume in five graduated steps. This combination of IC1 to IC3 we shall refer to as a single "module".

A number of sub-assemblies of this module are used, depending on the number of speaker channels that your audio system possesses. One module in its entirety is the "master" or "parent", and the others, which are "cut down" versions, are the slaves. Their make-up is discussed later.



Parent "module" plus slave modules

Volume Control

Let us first consider the volume control more closely. Analogue multiplex selector IC1 is the basic volume control and is controlled by oscillator/ripple counter IC2, which is wired as a 3-bit counter. IC2 is theoretically capable of controlling up to fifty such volume controls simultaneously, each of them operating in sync with its neighbour.

Further, each volume control may be offset from its neighbour, so that, for example, as one volume control cycles through high volume, its neighbour cycles through low volume, and vice versa. This means that as one channel "fades in", the neighbouring channel may "fade out". That is, a sound may be made to shift from one speaker to the next and back again. Using two modules, this would occur in eight discrete steps, as shown in Fig.2.

This having been said, the two speakers need not be synchronised with each other. The basic module is so designed that it may also function independently of its neighbour. Therefore two or more modules could shift the sound around independently of each other, in random fashion.

There are further possibilities. For instance, eight modules could be wired in sync, each being offset a single step from its neighbour. Thus the volume could be shifted around all eight speakers. Imagine that these eight speakers were placed around the perimeter of a room. A single stereo channel could thus be made to "chase" around the room – alternatively, two stereo channels (two times eight) could chase around the room, perhaps in opposite directions.

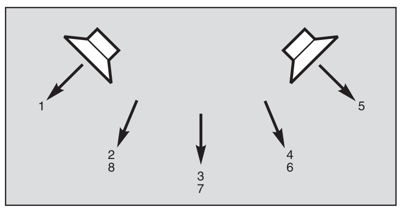


Fig.2. Sound motion in eight discrete steps

But we are getting beyond ourselves, since this would involve sixteen speakers, with up to 16W r.m.s. output – assuming that the suggested amplifier device were used for IC3. This would be enough to rattle the windows and have the neighbours' dogs barking.

Two speakers, however, are sufficient for a startling effect, and just three would be capable of shifting a sound through 360° in similar fashion to a Hammond speaker. Details are given later for building a two-speaker system – and for expanding this to three or four or more.

Other Effects

Perhaps best of all, this circuit may exploit the Haffler effect – so named after David Haffler, who first employed the difference signal between stereo channels to obtain an extraordinary effect.

In any stereo recording, there are nearly always sounds which are common to both channels, and sounds which predominate in one or the other channel. Any sound that predominates may be fed to a third channel. This leads to some interesting effects. A particularly striking effect is obtained with applause, which in a stereo recording tends to be markedly different in each channel.

Thus any applause is drawn to the fore by this system. When this is shifted around a room, it brings the applause to life as few stereo recordings are able to do. Similarly, the author found a particularly striking effect with African cheering (in some African music, an audience may cheer in time with the music).

Not only does this circuit make it possible to shift or rotate sound around a room. The choice of the TBA820M for amplifier IC3 makes it possible to adjust the upper frequency roll-off of the amplifier by means of a single component, capacitor C7. Therefore one may also shift tones around a room, although in a rudimentary fashion. With a three-speaker system, this could seamlessly shift the tone from treble to "mid" and back again as it travels through 360°.

This bears some similarity to the electronic organs of the legendary Laurens Hammond, who achieved such an effect with an organ which contained a mechanically rotating speaker. This he also combined with mechanical tone wheels, so that both the sound and the tone shifted around a room. The present circuit is, of course, hardly worthy of the name Hammond – yet it represents a very cheap way of obtaining a simple approximation of the sound – thus the name "Solid State Hammond".

Other Uses

Besides the above, several other audio effects would be possible. For instance, a stereo tremolo unit could be built. Alternatively, the unit could be used with one of the instruments of a live band, to shift the sound around the "sound stage" – for instance, the drums. Not least, the circuit could be used "in reverse". With just a little modification, it could be used to record stereo signals in such a way that they would travel from speaker to speaker in the final playback. This was used to dizzying good effect by rock bands in the 1960s and 70s.

Design Development

Long before the final project made it off the workbench, the author considered (and tested) a few other approaches to the idea. The first idea was simply to switch three loudspeakers in sequence, so that a sound would travel through six positions in a room. The idea was elegant in simplicity – but alas, it was doomed to failure from the start, as any electronics enthusiast might have guessed. The thumps and pops produced by this method truly scuppered the attempt.

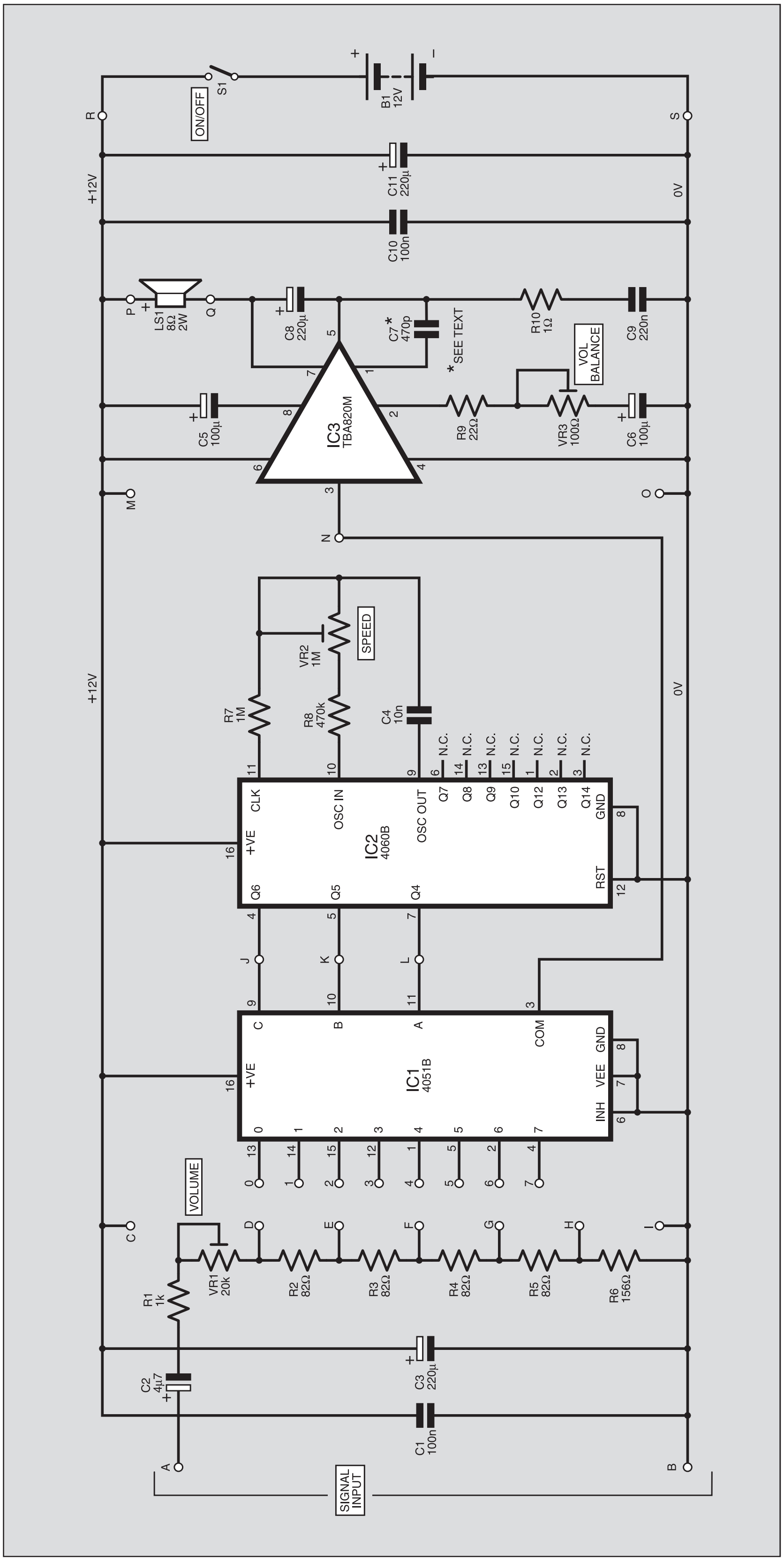


Fig.1. Circuit diagram of the Solid-State Hammond

Not only this, but solid state switching introduced far too much distortion (switching through relays would of course have been thoroughly unsatisfactory). The author then considered that, instead of switching the loudspeakers, he might switch a number of amplifiers in sequence.

However, this too was destined for failure, for much the same reasons – namely thumps and pops in the loudspeakers.

A third attempt was made, this time adjusting the gain of the amplifiers in sequence. For this, the author adjusted the conductance of f.e.t.s to control the gain.

COMPONENTS

Resistors — See SHOP TALK page

R1	1k
R2 to R5	82Ω (4 off)
R6	150Ω
R7	1M
R8	470k
R9	22Ω
R10	1Ω

All 0.25W 5% carbon film or better

Potentiometers

VR1	20k preset (see text)
VR2	1M preset (see text)
VR3	100Ω preset (see text)

Capacitors

C1, C10	100n polyester (2 off)
C2	4μ7 radial elect. 16V
C3, C8, C11	220μ radial elect. 16V (3 off)
C4	10n polyester
C5, C6	100μ radial elect. 16V (2 off)
C7	470p ceramic (see text)
C9	220n polyester

Semiconductors

IC1	4051B eight-stage analogue multiplexer
IC2	4060B oscillator-ripple counter
IC3	TBA820M 2W audio amplifier (see text)

Miscellaneous

LS1	8Ω 2W loudspeaker
S1	s.p.s.t. switch

Printed circuit board, available from the *EPE PCB Service*, code 545; suitably rated power supply or batteries, battery holder or clip; 16-pin d.i.l. socket (2 off); 8-pin d.i.l. socket; speaker cable; sheathed single-core wire; link wire; solder pins; solder, etc.

Approx. Cost Guidance Only **£12** *per module* *excl case, loudspeaker and batts*

This worked after a fashion, but the method proved to be a little complicated, a little too tricky to make it safely repeatable, and it depended too heavily on a specific i.c., which would have limited the project's versatility.

This led to the present approach, namely a digitally adjusted potentiometer at the amplifier input. In this case, the author further decided on discrete CMOS components for the volume control, IC1 and IC2, since dedicated potentiometer i.c.s tend to be difficult to locate in parts of the world – as well as being far more likely to become obsolete.

There are two main advantages to the present approach. Firstly, one does not need an up-down counter to increase and decrease the volume. A single counter cycles the volume endlessly through high and low. Secondly, the present system enables one to use almost any amplifier of one's choice, since the volume control is not designed as an integral part of the amplifier, but as a "front end" to its input.

Weak as a Feather

The circuit does have a few weaknesses, however. While these hardly have any perceptible effect on the sound, the author is led to believe that some audiophiles will hear a feather alight on a felt cushion – therefore these had best be noted!

Firstly, the eight-stage analogue multiplexer IC1 cycles the volume through five fairly "chunky" steps. While this would not normally be perceptible, the volume control could fairly easily be refined with the use of a 4061 sixteen-stage analogue multiplexer and the additional use of IC2 output Q7 to provide the required 4-bit binary counter. The 4051 was used in this project for the reason that a 4061 would have made it bulkier and more complex.

Secondly, whenever IC1 switches between outputs, it introduces a very faint "click" into the signal being multiplexed – particularly when switching to output channel 0. This "click" is far quieter than the tick of a quartz clock on the wall. However, see the remark on audiophiles above! This "click" should generally be imperceptible.

Thirdly, IC1 introduces varying levels of very slight hiss as the sound is sequenced through output channels 0 to 7. This is also generally imperceptible.

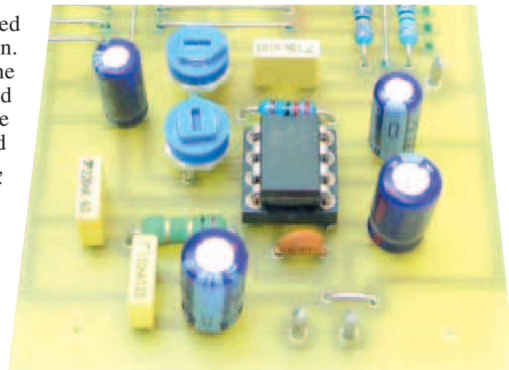
More Circuit Details

As previously said, the basic circuit as shown in Fig.1 is very simple. It begins with potential divider VR1 and resistors R1 to R6. These divide the input signal into five discrete potentials. This input is taken directly from an existing amplifier's loudspeaker. You may experiment with the values of R1 to R6, on condition that you limit this to 50% or so variation.

If you wish to exploit the Haffler Effect (which would be well worthwhile), the input would be taken from the two positive terminals of the stereo speakers. In this case, the stereo amplifier and the Solid State Hammond project should **under no circumstances use the same power supply**, otherwise the amplifier could be damaged.

An earlier prototype omitted VR1 and used only VR3 at the amplifier to control the volume. However, this introduced hiss and distortion at higher gain. Therefore VR1 is used to control the volume, and VR3 should be used merely to balance the volume between the modules and it should be turned back as far as possible, with VR1 being the adjustment of choice.

Component IC2 is a 14-stage oscillator and ripple counter, which is wired as a 3-bit counter. This sequences analogue multiplexer IC1 through its eight stages. These two i.c.s are wired as a solid state potentiometer, so that the potential across VR1 to R6 is tapped in sequence, in a continuous cycle.



Close-up of the amplifier module section

This, in turn, controls the volume of a 2W r.m.s. amplifier, IC3, so that its volume continually fluctuates. VR2 controls the speed of fluctuation, and the values of R8 and C4 may be changed if desired. As a matter of interest, it would be possible, simply by switching the A and C binary inputs of IC1 (pins 9 and 11), to make the volume in the loudspeakers jump in more rapid and jerky steps. This might be suitable especially for more rapid music such as jazz, where a smooth "motion" from speaker to speaker might not achieve the desired effect.

Amplifier Module

There is little to be said about amplifier module IC3, which is a standard 2W r.m.s. type, TBA820M, wired in keeping with the manufacturer's recommendations. This was selected for three reasons in particular:

Firstly, the TBA820M has a very high input impedance (5MΩ). Therefore several such amplifiers may be wired together ("in sync") without overloading the input arrangement VR1 to R6.

Secondly, the TBA820M has a 2W r.m.s. output at 12V (some would find the distortion at 2W unacceptable, therefore it is sometimes rated lower than this). Since this project creates a "background" effect, which would not typically require high volume, 2W r.m.s. was considered to be adequate. While this may not seem much in an age where small "ghetto blasters" frequently advertise a few hundred watts p.m.p.o., 2W r.m.s. is in fact beyond the level of comfort for continual listening in a typical lounge.

This having been said, the TBA820M may easily be replaced with virtually any other power amplifier, with IC1 pin 3 (point N in Fig.1) being taken to the amplifier's input. In this case IC3 and its attendant components may simply be omitted from the p.c.b.

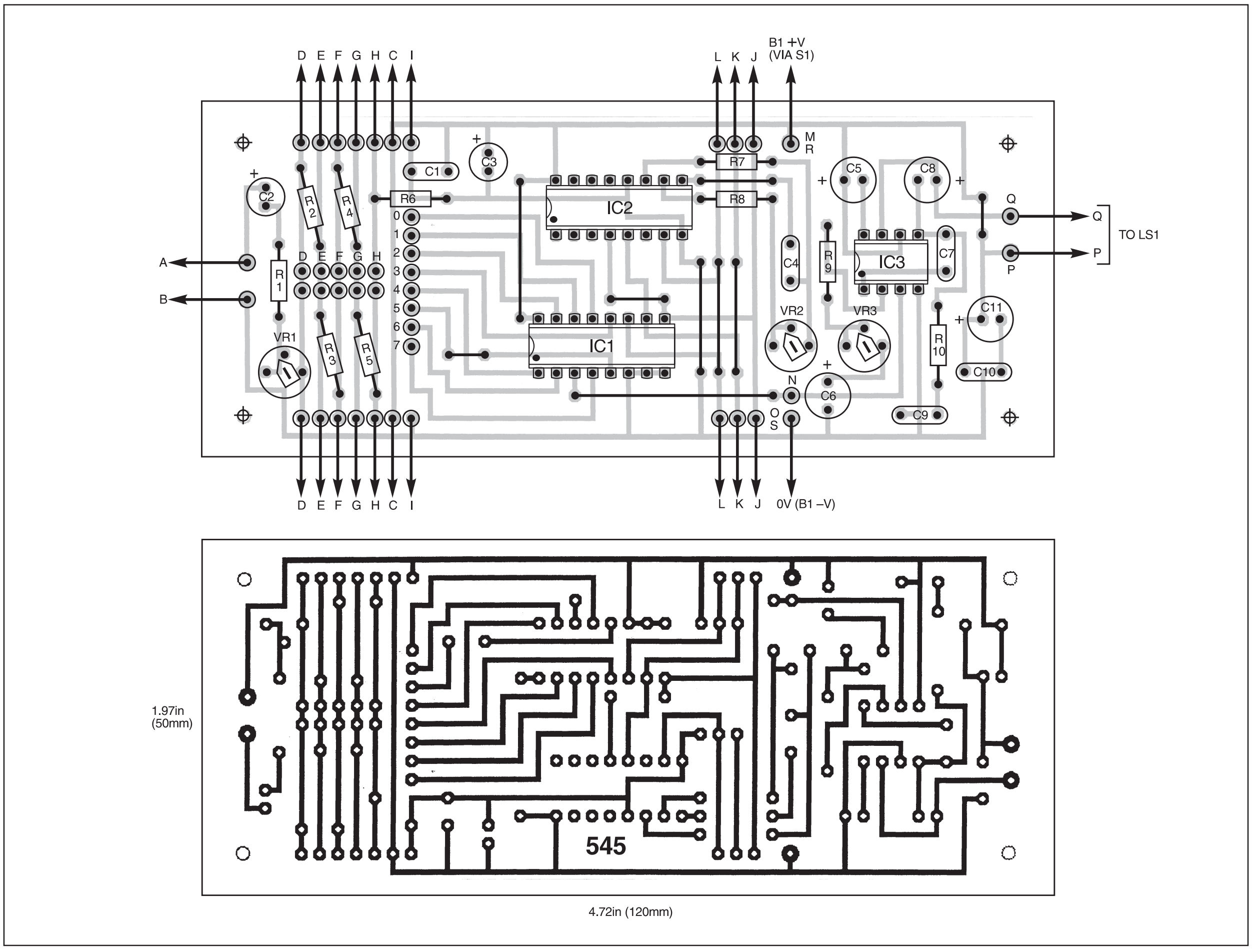


Fig.3. P.C.B. layout, wiring and full-size track for the Solid-State Hammond

It needs to be noted, however, that if an amplifier has low input impedance, this will limit the number of modules that may be wired "in sync".

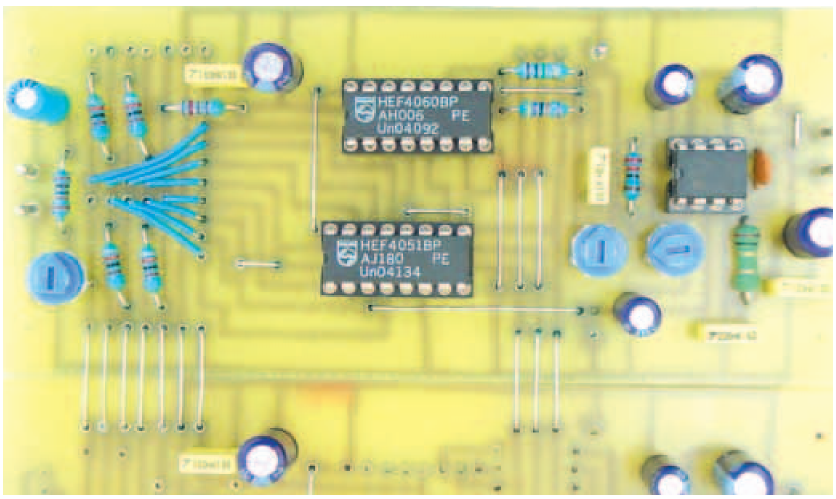
Thirdly, it is possible, with IC3 as a TBA820M, to control the tone in a rudimentary way through the value of capacitor C7. The present value for C7 limits high frequencies to roughly 13kHz, while a value of 1n to 2n2 would bring this down to a "mid" range. The advantage of a rudimentary tone control is that, not only may the sound be shifted around, but also the tone – as was the case with the Hammond organ.

Points D to H in Fig.1 are suitably wired to inputs 1 to 7 of IC1, in order to control the phasing (or syncing) of the modules. This is described later in greater detail.

Further, points C to I are "jumped across" from one module to the next – unless you should wish to give a module independent timing, in which case points J to L are not joined (see below). Points M and O are not connected between boards. These are finally used to connect the power at the two sides of all the paralleled modules.

Construction

The printed circuit board component and track layouts are shown in Fig.3. This board is available from the *EPE PCB Service*, code 545. You need the same quantities of this board as the number of amplifiers you wish to control.



The complete parent "module" for the Solid-State Hammond showing the links to the next module

One board should be assembled as the main or "parent" module, using all the components shown in Fig.3. All "slave" modules are paralleled with the parent module, omitting C2, R1 to R6, VR1, and IC2 with its attendant components R7, R8, C4, and VR2. This is seen in the photograph on the first page with the parent module in the foreground, and slave modules in the background.

If, however, a slave module is not to be used in sync with the parent module, IC2 with its attendant components are retained. If another amplifier is to be used in place of the TBA820M, IC3 and all its attendant components may be omitted from the p.c.b.

Begin by soldering the solder pins. Insert and solder the dual-in-line (d.i.l.) sockets for the i.c.s. Solder the nine link wires. Then solder all the resistors, preset potentiometers and capacitors – taking careful note of the polarity of the electrolytic capacitors.

Syncing

Next, the "syncing" of each module needs to be suitably wired up. To make this easy, the wiring is shown in Table 1. Simply match this with the labelling shown in Fig.3 (next to R1), using eight short lengths of sheathed wire to make the connections. In concept, this is simple – feed the discrete potentials at points D to H into IC1 inputs 0 to 7 as suits your purposes, bearing in mind that IC1 sequences through inputs 0 to 7 in that order.

Next comes the joining of the parent module with slave modules. Jump wires are taken from points C to I on one board and are wired to points C to I on the neighbouring board. Then jump wires are taken from points J to L on one board and wired to points J to L on the neighbouring board. However, if a slave module has independent timing (that is, if IC2 is on board the slave module), points J to L should not be wired up.

Two leads are taken from your hi-fi system's speakers to solder pins A and B (these are only taken to the parent module), and additional speakers are wired to each module's solder pins P and Q, taking note of speaker polarity.

Then the power is attached to points M (+VE) and O (0V). Be sure not to confuse these two points, or the modules may emit smoke in sequence! If another amplifier is to be used, this is attached to points M, N, and O.

Table 1: Syncing Wiring for the Modules

	Two Speakers		*Three Speakers*		
	Module 1	***Module 2***	***Module 1***	***Module 2***	***Module 3***
○ ○ D	D.....0	D.....4	D.....0	D.....3	D.....6
○ ○ E	E.....1	E.....5	E.....1	E.....4	E.....7
○ ○ F	F.....2	F.....6	F.....2	F.....5	F.....0
○ ○ G	G.....3	G.....7	G.....3	G.....6	G.....1
○ ○ H	H.....4	H.....0	H.....4	H.....7	H.....2
	G.....5	G.....1	G.....5	G.....0	G.....3
7 6 5 4 3 2 1 0	F.....6	F.....2	F.....6	F.....1	F.....4
○ ○ ○ ○ ○ ○ ○ ○	E.....7	E.....3	E.....7	E.....2	E.....5

Finally, presets VR1 and VR2 could be replaced with panel mounting potentiometers for easy access from the case. These respectively control the volume and the speed at which the sound fluctuates.

Setting Up

A mid-way setting for VR1 should be suitable to begin with, if the hi-fi system's volume is not turned up too high at first. Each VR2 is also first turned to a mid-way setting. Each VR3 should be turned right back for the lowest volume.

Connect the power. If you listen very closely, there should be faint surges of hiss in each module's loudspeaker. Now play a stereo recording through your hi-fi. If you do not know which are the positive terminals of your hi-fi speakers, you may experiment until the desired result is obtained. It should be obvious which are the two positive terminals when the Haffler effect kicks in. This should obviously differ from the "background" sound of both speakers.

The possibilities in mixing and matching modules are legion – not to speak of the various possibilities that exist for mounting loudspeakers in a room. From here on, the configuration of the Solid State Hammond is largely up to your ingenuity and experimentation. It would be possible to start with a single module and to test this, then to add modules one by one as desired.

If relatives and friends were to buy you a Solid State Hammond p.c.b. and components for every auspicious occasion in your life, you might soon have a few tens of modules operating "in sync"! ☐

READOUT

Email: john.becker@wimborne.co.uk

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All letters quoted here have previously been replied to directly.

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★ LETTER OF THE MONTH ★

A Hidden Danger

Dear EPE,

I recently examined an audio amplifier for a sub-woofer loudspeaker, and found a dangerous but easily made wiring error that will not show up in normal tests. It has a toroidal mains transformer bolted, in the usual way through its centre, to an aluminium chassis forming part of the overall bare metal case. We all know that you must not make any connection round the outside of such a transformer between top and bottom of the bolt as this constitutes a shorted turn and a heavy current could flow in it.

This amplifier had a kettle type mains input plug with the earth wired conveniently to the nearby top of the transformer fixing bolt, at the end remote from the chassis. On the face of it this is all right as there is no direct connection from the earth pin in the plastic plug to the chassis, and all normal testing done on it would show no problem.

Consider what could happen in use. Another earthed metal item could easily come into contact with the amplifier case, especially where a concert will have all sorts of equipment on the stage, perhaps standing on top of the amplifier – we can't rely on everything having insulated feet – or next to it. There is now a shorted turn from the fixing bolt to the earth pin in the amplifier plug, through the earth wires in the mains leads to the other case and via the contact with the chassis of the amplifier to the bottom of the bolt.

This could be dangerous. Imagine this happening out of sight at the back of the stage, with the two chassis not quite touching until vibration brought them together, it could easily start a fire from sparks at the contact point. Although the voltage on a single turn is low, the inductance of the transformer may create the sparks on intermittent contacts.

Have I exaggerated the danger? I don't know, I haven't confirmed this experimentally! But, needless to say, I have moved the earth connection in the amplifier to a safe position directly on the chassis.

The Golden Rule is that it is extremely important not to make any connection at all to the bolt fixing a toroidal mains transformer.

Harry Weston, via email

That sounds horrendous, Harry, and readers should certainly be aware of this possibility. Thank you.

USB, Analogue TV and Batteries

Dear EPE,

Is anything more in the offing about writing software to and from USB sockets. I have an interesting problem in that while I have USB2 cards on my USB1 computer. They persistently fall over and I am told that I've got to live with it or buy another computer, which I find hard to believe.

I have another interesting project in mind. My Yamaha HX1 organ has an edge connector port where you can plug in a memory card. Well, you could before they went obsolete. Hugely expensive and they only stored about 8K to 32K of data as a maximum.

Now I feel it would be possible to slot in one of these ever so cheap 16M digipix cards, but this is another area where there is almost no published information on using them or even the pin connections for that matter.

As usual in these days of information technology, information from the manufacturers is absolutely impossible to get. Usual platitudes about insuring your personal safety are often quoted as the excuse, but it's actually the usual closed shop. It's a very great pity that us consumers have never managed to form an association which demands information and refuses to buy if it's not forthcoming.

Regarding the "death of analogue TV", as a person who has in the past built his own black-and-white television set followed by actually being one of a few who managed to get to work a misbegotten design of a colour television set that was in one of the mags some years back. I feel I must put in my two pen'orth.

Well, if you live in North London digital it is virtually forced on you because of the multipath ghosting caused by high-rise buildings in the surrounding area. I personally would demand that anybody who simply has got to build the tallest building around should have to donate for free the top floor to house a set of TV transmitters and put the aerial on top. Digital seems to be the only way out.

Freeview boxes are for sale under £30 now so don't really present a problem fitting one to each unit you have in the house. There are even things which allow you to pre-program the Freeview box and the recorder to your requirements.

Also, does anybody know anything about Ni/Mh battery life related to size? I have lots of Nicad AA batteries that are years old and still retain their charge but from a set of six AAA Ni/Mh ones that came with a pair of portable wireless house phones, four have died well within a year, and all the usual tricks of high current or voltage pulses have not revived them. Strange thing is they will not discharge fully either.

Like my four year old car battery – built in hydrometer says fully charged but 48 hours after charging the thing is flat again. These days there is no way to look down the topping up holes to check as there aren't any. I surmise that it has dropped several plates and its amp hour capacity is almost nil.

George Chatley, via email

We've nothing more on USB at present George, but I wonder if readers might have any comments on your problem, or can offer advice on the batteries? And, George, you are not on your own regarding thoughts about analogue and digital TV!

Digital Terrestrial TV

Dear EPE,

Congratulations to Ken Wood for his letter on Digital Terrestrial TV (Sep '05), with which I heartily agree. I would like to add a few comments about the introduction of digital terrestrial transmissions. When the channel allocations for Bands 4 and 5 were originally worked out in the early 1960s, it was on the basis of up to four programmes in each area, and with the minimum chance of interference. So in any one area, the programmes are spaced three or four channels apart to avoid adjacent channel interference, and with the spacings not all equal so that any third order intermodulation products generated in the front end of the receiver will fall in unused channels.

The introduction of Channel 5 upset the scheme, and led to various problems, and many people are unable to receive it satisfactorily. The situation has been made much worse with the introduction of Freeview, which has been slotted in between the analogue channels, in many cases on the immediately adjacent channel to an analogue programme.

In order for this to work at all, the digital transmitters are run at a much lower power than the analogue; in the London area for example the analogue transmitters run at 1,000kW e.r.p. for each of the main four programmes, but the digital transmitters are only 20kW e.r.p., i.e. just one fiftieth of the power. So most people are going to need a much better aerial and many will not be able to receive the digital signals at all. A booster amplifier is not the answer, because this will reduce the dynamic range and increase the possibility of intermodulation products from the analogue signals clobbering the digital signals.

I get particularly annoyed with the BBC adverts that keep telling us how simple it is to go digital when this is far from the case, as Ken Wood made very clear. If I go to the Freeview website and put in my postcode, it tells me I can't receive digital at all, yet I get excellent analogue signals on all five channels.

Of course, the digital transmissions should have been in an entirely different part of the spectrum, as was the case with DAB, but there isn't the space available – unless of course you go to satellite transmission. How about Freeview from satellite with no subscriptions? Now there's an idea...

David Sharp, via email

Thanks for that David. You might find Techno Talk *in this issue interesting!*

Copy Protection

Dear EPE,

In his very interesting article "Renewable Copy Protection" in *News* Nov '05, Barry Fox states that "Because DVD's supposedly unhackable copy protection ... was defeated. A hacker simply sucked the de-encryption keys out of a legitimate player and grafted them into simple free software called DeCSS." He goes on to state that "DeCSS now lets anyone with a PC copy a DVD movie to a blank disc." There are a few problems with these statements:

DeCSS does not "suck" decryption keys out of legitimate players. It does not need to – CSS is a very weak encryption algorithm, and even changing the player keys would not prevent it being attacked. The people who designed CSS thought that they could prevent it being attacked by keeping it secret (security through obscurity). This strategy failed, as it always does. See **www.lemuria.org/DeCSS/crypto.gq.nu/** for more details.

DeCSS was not created by a "hacker" or someone intent on enabling illegal copying. It was created by various people (details are disputed) who wanted to be able to watch legitimately purchased DVDs using a computer running the GNU/Linux operating system. Previous DVD player software only ran on proprietary operating systems such as Microsoft Windows (despite what the authors of some *EPE* articles seem to assume, not everybody uses Windows.

The problem with a lot of copy-protection systems is that they provide far more power to content owners than does copyright law itself. Copyright law in most countries provides for "fair use" rights. If I legitimately purchase a DVD, nobody should be able to dictate what hardware or software I use to view it, whether I can lend it to a friend or sell it second-hand, how many times I can watch it, where in the world I can watch it, or whether I can watch it at all without giving personal information to unscrupulous commercial entities. None of the above activities constitute copyright infringement, but CSS and its more advanced cousins are designed to ban them nonetheless, without having any noticeable affect on stopping piracy.

Joe Rabaiotti, via email

Thank you Joe

Regen Receivers and Photic Communications

Dear EPE,

I used to play around with regenerative receivers (especially of the super-regen variety) many years ago – when the world was young! In those days it was considered good practice – if not essential – to buffer any regenerative stage from the aerial by either a wide-band or tuned front end. This helped prevent the device radiating and avoided upsetting the neighbours, and also dawn raids from the heavy mob from the interference suppression people (was it the PO or HMSO?). I am sure that a couple of designs in recent *EPE*s do not take this precaution.

Photic Phone (Oct '05): What is the legal position on using these devices? I remember many years ago when the government extended the spectrum coverage such that visible light etc. came under licensing laws there were all sorts of restrictions placed on line of sight devices.

In fact if I remember correctly one interpretation of the law would require a licence to wear spectacles! I have a feeling that if used within your own premises it is probably ok, but if used to communicate between two premises and especially across a public road there could be a problem.

Alex Duncan, via email

Regarding R-gen, I have no opinion to express, other than to say that the designs we published have been fully tested by their designers and have not suffered from the problem you express. We'd be interested to hear from other readers on this point.

On photics – no, I can't really see there'd be any restrictions on this technique, any more than there are with fibre- or opto-electronics between PCs etc, or kids using ex-WW2 Morse lanterns for comms, as I once used to (they're still around in junk shops, by the way).

Salutations

Dear EPE,

I really salute you. After dealing in electronics for five years, I had buried it in another career, though electronics was a passion for me. *EPE* was the reason I got back two years ago, mostly reading the theories, and the circuits with great interest, not only recovering the knowledge I had, but adding a lot more to it, encouraged by the fact that not much has changed in theory since 20 years ago.

But the electronics world is fascinating, especially with PICs adding flavour to it. I'm even thinking of creating a club for electronics hobbyists, where they gather, make projects, and research in everything related to the hobby. I don't know, it's like a dream, but everything starts from the mind. I was following the *PIC Tutorials* the "guru" John had written, and was wondering that, in the program of the real time clock, if the instruction cycles of the program had influence on the timing of the clock? I would appreciate explanations of 16F877 differences from 16F84 in programming.

Thank you so much guys, and keep inspiring people.

Eddy Rafi Kabakian, Beirut, Lebanon

Thanks for that Eddy. Yes, the number and type of commands does affect the timing. Some commands may take one clock cycle to perform, others may take two, while yet others may vary between one and two cycles, depending on the result of the command, such as with commands BTFSS and BTFSC. You need to study the PIC's datasheet to know the command timings – they are all quoted there.

Differences between various PICs are too great to detail, but go to ***www.microchip.com*** *and download the datasheets for those you are interested in. They're free. Once you know one PIC you'll easily get into most others.*

Club Head Speed

Dear EPE,

I am looking for a device to measure the speed of a golf club head as it passes through impact with the golf ball. Speeds in the range of 40 to 110 miles per hour are expected. Do you have anything in your back catalogue of projects that would do the job?

Ross Wright, via email

Ross, I've often thought it would nice to do something similar, e.g. as for tennis, but I'm not actually sure how the sensing is done and have never pursued it, so for the moment I must say we have nothing to offer you. Let's see what readers might say.

FR4 Laminate Again

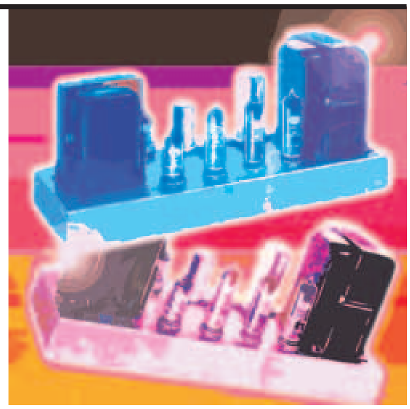
Dear EPE,

In *Readout* Oct '05, Paul wanted to know where to get unclad FR4 laminate. Tell him to try **Vulcascot.co.uk** or **RAK.co.uk**.

Pat Darragh, via email

Thanks Pat, that's helpful – there you are Paul, and others!

Solid-State Valve Power Supply



Stef Niewiadomski

A low voltage converter for powering your prized valve equipment, including vintage radios and amplifiers etc. Can supply up to 200V at 100mA plus 6V at 1A

OVER the past few years experimenting with valves has become a popular pastime. We are seeing two groups of constructors with this interest: "old-timers" recapturing their youth and maybe trying to get that valve circuit they built many years ago finally working, and newcomers who want to try this old technology "and see them glow". Whatever the motive for playing with valves, the first task facing a constructor is to build a power supply unit (p.s.u.), giving the high tension (HT) and low tension (LT) voltages needed for the valves.

The valve p.s.u. described here generates these voltages from a low voltage d.c. supply source, therefore avoiding the safety issues of deriving them from the mains, but be aware that the HT voltage generated by this project is still dangerous. It is capable of supplying an HT voltage of 200V at 100mA plus 6V and 12V at 1A for the heaters (LT). It also avoids the expense of buying a special mains transformer with heater/filament windings, which are becoming harder to find and more expensive. (We shall use the vintage radio term "heaters" when referring to the valve's filament or LT connections.)

The p.s.u. can be used as a self-contained bench unit, or alternatively the printed circuit board (p.c.b.) and transformer can be incorporated into a piece of standalone valve equipment, such as a vintage radio or amplifier.

What Voltages ?

Most valve circuits are remarkably tolerant of the HT supplied to their anode circuits. This circuit is no exception, when supplied with an input voltage of 13·8V d.c. it provides around 200V d.c., at up to about 100mA. By reducing the d.c. supply to the unit, the HT output can be reduced down to below 80V. A figure of 90V is a useful HT voltage, commonly used in battery-powered radios, for which special sets of valves were developed.

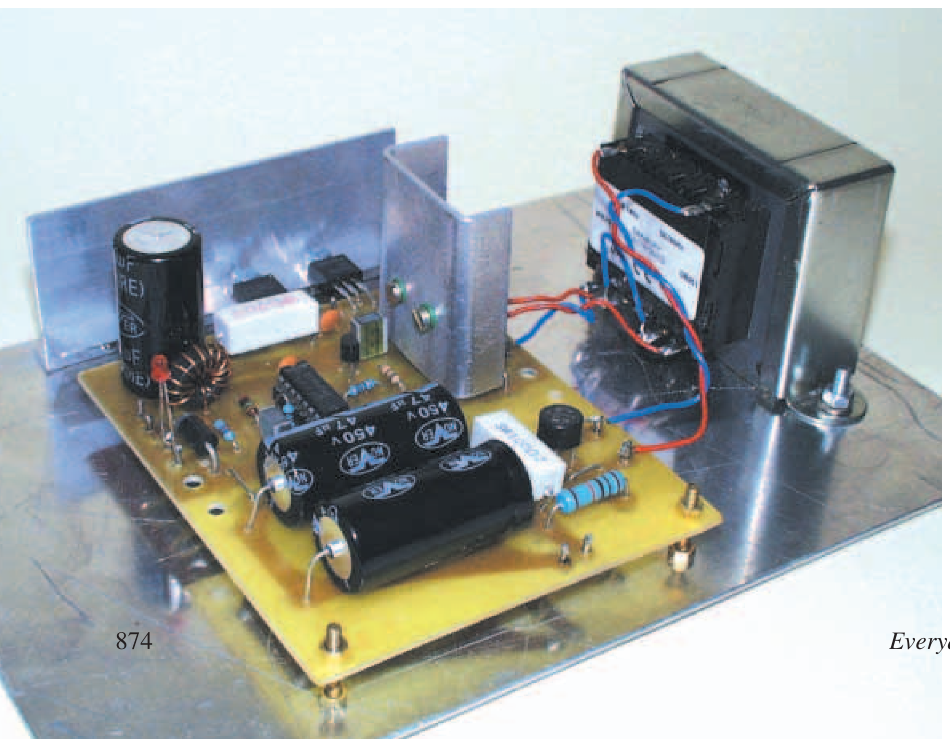
Of course, valves also need an LT voltage to supply their heaters. Two common voltages are used: valves whose part number begins with a letter "E" (for example the EF91) need a 6·3V heater supply, In the US, 6·3V valves (or tubes) begin with a number "6", such as the 6AU6; which seems very logical.

The second common heater voltage used is 12·6V, commonly used in "double" valves, where two diode, triode or pentode functions are included in the same glass envelope. These typically have numbers starting with "ECC" or maybe "ECF" Again in the US, 12·6V valves begin with the number "12" for example the 12AU7.

From a current point of view, 6·3V heaters typically consume 300mA and 12·6V heaters consume around 150mA.

In valve power supplies powered from the mains, the mains transformer usually has a separate 6·3V or 12·6V winding (or sometimes multiple windings) which supplies the heaters with a.c. The 6·3V or 12·6V voltages we glibly use are r.m.s. values and therefore equate to the heating effect of the voltage, and so can be exchanged for 6V d.c. and 12V d.c. supplies with no ill effect.

In fact supplying the LT with d.c. rather than a.c. has the benefit of making it easier to keep mains hum out of the valve equipment. This unit generates 6V and 12V d.c. voltages for the valve heaters.



Circuit Description

The full circuit diagram for the Solid-State Valve Power Supply is shown in Fig.1. The external d.c. power supply input (+13·8V) is filtered by r.f. choke RFC1 and the large reservoir capacitor C5. The d.c. input power can be supplied either from a fixed 13·8V supply unit, commonly used for powering amateur transceivers, or a variable power supply. In the author's opinion, these fixed 13·8V power supplies are a cheap way of obtaining a high current, relatively noise-free, stabilized d.c. voltage. See below for the current rating needed for the d.c. supply.

Diode D1 and fuse FS1 protect the p.s.u. from being connected to the external d.c. supply the wrong way round. The external Power On is indicated by l.e.d. D2, and its current is limited to about 10mA by resistor R8.

Note which way round diode D1 is connected in circuit: if the external supply is connected correctly it never conducts and all is well. However, if the supply is reversed, that is with a negative voltage at

its cathode (k), the diode conducts heavily with only about 0·7V across it, and sufficient current flows to blow fuse FS1 within a few hundred milliseconds, disconnecting the supply and hopefully protecting the unit from damage.

The filtered d.c. input voltage is fed to voltage regulators IC3 and IC4 which produce stabilized +12V and +6V at their respective LT outputs. Resistor R9 reduces the power dissipated in IC4, since the regulator would have to drop 13.8V minus 6V = 7·8V, and therefore with a 1A load would have to dissipate 7·8W if R9 were not included. Also, both regulators are provided with a heatsink, but in the case of IC4 this dissipation is shared between R9 and IC4.

Inverter Oscillator

An oscillator, whose frequency is determined by capacitor C1 and resistor R2, is formed by IC1a, IC1b and IC1c. The formula for the frequency of oscillation is given by: Freq = 0·455/C1 × R2. With the values shown on the circuit diagram, the prototype oscillated at about 53Hz, which was considered close enough to 50Hz to make no significant difference. This 3-inverter oscillator produces an output with a 1:1 mark-space ratio, which the more common 2-inverter version is less likely to do.

The output of IC1c (pin 6) drives the series combination of inverters IC1d and IC1f, and also inverter IC1e. This results in the output pins 12 and 10 of IC1 being in anti-phase with each other. These outputs drive, via resistors R3 and R4, the gates (g) of power MOSFETs TR1 and TR2 whose drains (d) are connected in a

COMPONENTS

Approx. Cost Guidance Only **£16**

excl case and transformer

See SHOP TALK page

Resistors

R1	1M
R2	100k
R3,R4	100Ω (2off)
R5	150Ω
R6	100Ω 2W
R7	100k 0·5W
R8	1k
R9	4Ω7 5W

All 0·25W 5% carbon film, except where stated

Capacitors

C1	82n polyester
C2	100n polyester, 250V
C3,C4	47µ axial elect. 450V (2off)
C5	4700µ radial elect. 25V
C6,C7, C8	100n ceramic disc (3off)

Semiconductors

D1	1N5401 50V 3A rect. diode or similar
D2	5mm red l.e.d.
D3,D4	BZX85 33V 1·3W Zener diode (2off)
TR1,TR2	IRF530 *n*-channel power MOSFET (2off)
IC1	74HC04 Hex inverter
IC2	78L05 5V 100mA voltage regulator
IC3	7812 12V 1A fixed voltage regulator
IC4	7806 6V 1A fixed voltage regulator
REC1	W04 400V 1·5A bridge rectifier

Miscellaneous

T1	230V mains transformer with 12V + 12V 1A secondaries, or similar – see text
RFC1	100µH choke, 14 turns 0.56mm (24s.w.g.) enamalled copper wire wound on toroid ferrite core – see text
FS1	5A 20mm fuse and fuseholder
S1	s.p.s.t toggle switch (optional)

Printed circuit board available from the *EPE PCB Service*, code 452; 14-pin d.i.l. socket; case (optional), size and style to choice; aluminium chassis plate, size 150mm x 220mm; aluminium plate for TR1/TR2 heatsink, size 60mm x 40mm (see Fig.3); aluminium angle plate for IC3 and IC4 (see Fig.3); TO220 semiconductor insulating kit (2off); multistrand connecting wire; 1mm solder pins; p.c.b. mounting screws and nuts; solder etc.

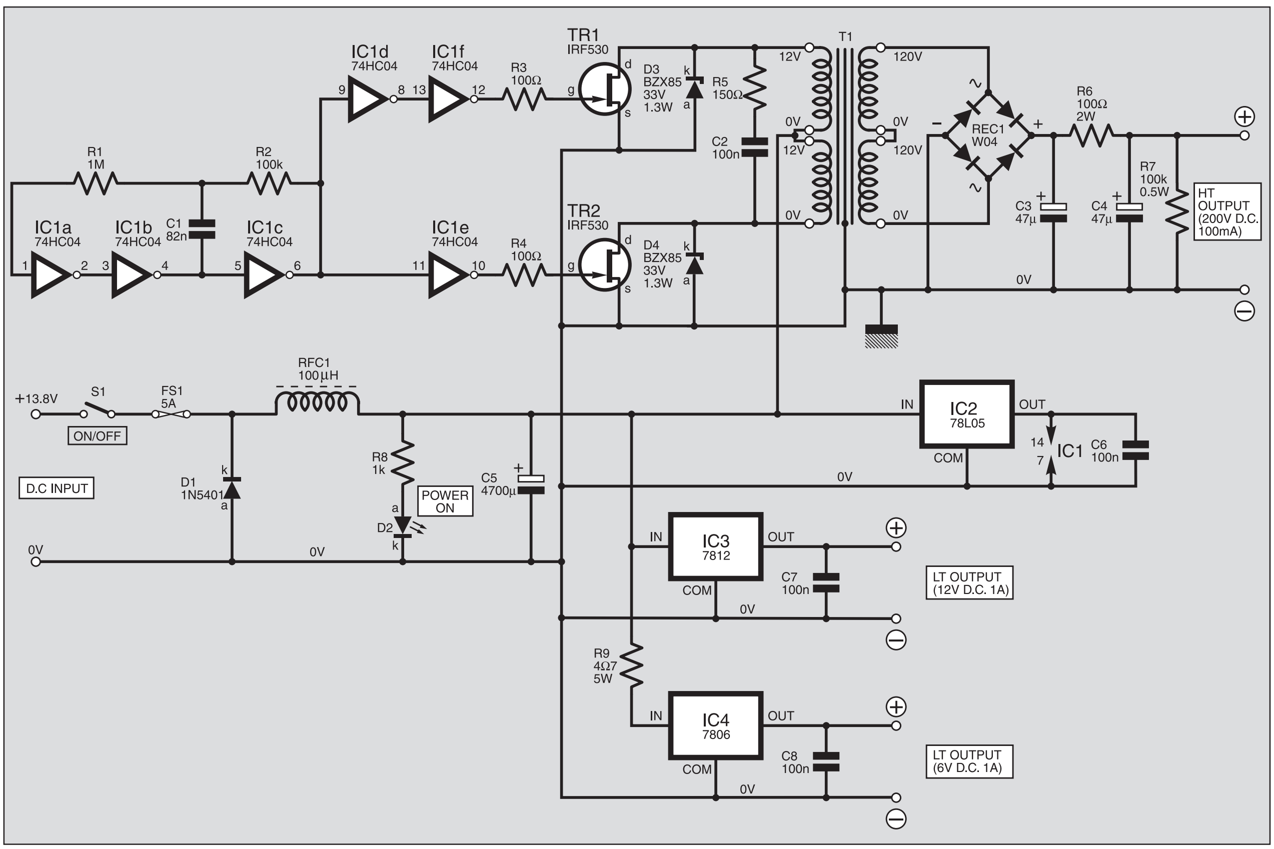
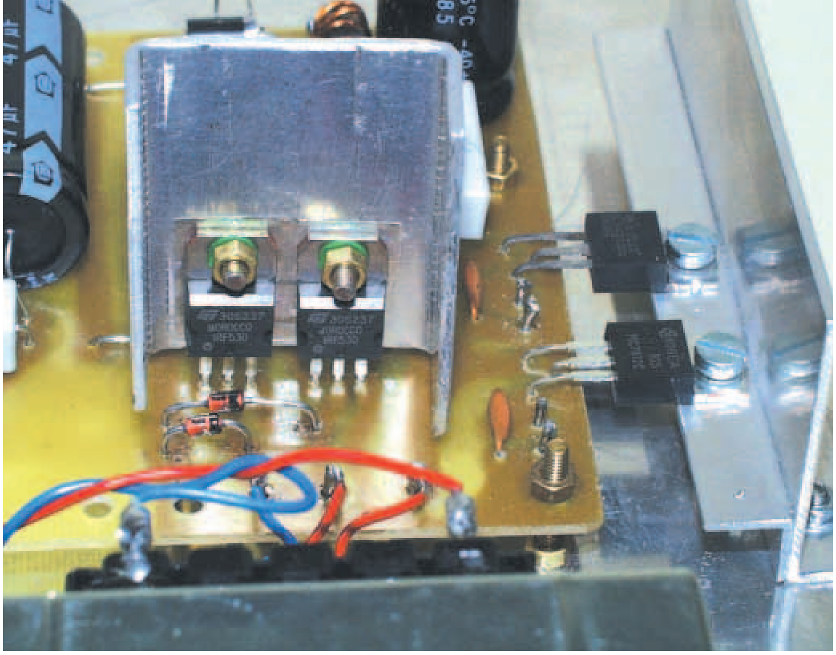


Fig.1. Complete circuit diagram for the Solid-State Valve Power Supply



You must use two semiconductor insulating kits when mounting the MOSFETs on the aluminium heatsink

push-pull configuration, driving the low voltage "primary" windings of transformer T1.

Voltage regulator IC2 provides the necessary stabilized 5V supply for the 74HC04 Hex inverter IC1.

The drains (d) of transistors TR1 and TR2 drive transformer T1, which is a normal 12V+12V mains type connected "backwards" i.e. secondary windings become primaries and vice versa. The original 12V windings are driven by TR1 and TR2 in antiphase with the centre-tap providing the positive voltage to the drains of the transistors.

The high-value reservoir capacitor C5 provides the high current peaks as TR1 and TR2 switch. Zener diodes D3 and D4 help limit any "spikes" at the drain terminals, which is also the function of the snubber network R5 and C2.

The "secondary" of transformer T1 gives a high voltage a.c. waveform output which is full-wave rectified by bridge rectifier REC1 and smoothed by capacitors C3, C4 and resistor R6. The final smoothed high voltage d.c. output (approx. 200V at 100mA) is available at the HT output terminal. Resistor R7 discharges the smoothing reservoir capacitors within about 10 seconds of switch off if an external load is not connected.

Construction

The prototype unit was built on a single printed circuit board and mounted on a sheet of 1·5mm thick aluminium. With the presence of such high voltages, it is recommended that the final assembly be housed in a suitable case. If desired, you can also include case-mounted input and output sockets.

The valve p.s.u. printed circuit board topside component layout together with the full-size copper foil master pattern and wiring to the transformer is shown in Fig.2. This board is available from the *EPE PCB Service*, code 542.

Mount the components in ascending order of size, taking care to correctly orientate the socket for IC1, the electrolytic capacitors, diodes, regulators and transistors. Insert 1mm terminal pins into the holes for the inputs and outputs to the board to facilitate off-board wiring, rather than trying to insert wires directly into the board itself.

Heatsinks

Transistors TR1 and TR2 are mounted "standing up" on the board and are fitted with an aluminium heatsink. The dimensions for this are shown in Fig.3(a).

Although TR1 and TR2 have a very low on-resistanceds, they still ran a little warm in the prototype at full load, hence the shared heatsink. *Take note:* The drains of these transistors are connected internally to their metal mounting tabs and therefore both transistors *must* be fitted to the heatsink using TO220 insulation kits, otherwise the drains of these transistors would be shorted together with disastrous results.

The pins of IC3 and IC4 need to be carefully bent through 90 degrees and the middle one offset from the outer ones, so that the regulators project horizontally from the p.c.b. for mounting on a common heatsink, details of which are shown in Fig.3(b and c). This heatsink is made from two pieces of aluminium angle bolted together – see photographs.

Some juggling of the heatsink position and the height of the p.c.b. above the chassis may be needed to ensure that IC3 and IC4 are not stressed in the final assembly. The tabs of IC3 and IC4 are connected internally to the middle common or ground pin, and therefore no insulating kit is needed when mounting them onto the heatsink.

Choking-Up

Rather than use an off-the-shelf choke for RFC1, one was specially hand-wound for the circuit. The reason for this is that all the current consumed by the various stages that make up the p.s.u., and the external current drawn from the LT outputs, flows through this choke and there was some concerned that the resistance of an off-the-shelf choke (typically 10 ohm) would drop too much voltage and waste power whilst also getting very hot..

Winding the choke (RFC1) is very straightforward. Simply cut a 30cms length of 0·56mm (24s.w.g. or similar) enamelled copper wire and wind about 14 turns on a toroidal ferrite ring core. This will give the 100μH inductance needed with a very low series resistance. Trim the ends of the winding, scrape off the enamel insulation, solder tin the bare ends of the leads and solder onto the p.c.b. as indicated in Fig.2.

It can be seen from the component layout diagram (Fig.2) that the board has been designed with the converter and LT circuitry separate from the HT rectifier and smoothing circuit. Two links connect the ground planes (0V) of these two sections together. If it suits your mechanical layout better, the p.c.b. can be cut in half and the resulting two boards mounted separately. Extra mounting holes have been allowed for in the p.c.b. to make it easy to mount these boards. If you do split the p.c.b., you will need to add wires to connect the HT negative (0V) rail to the ground (0V) plane of the LT section.

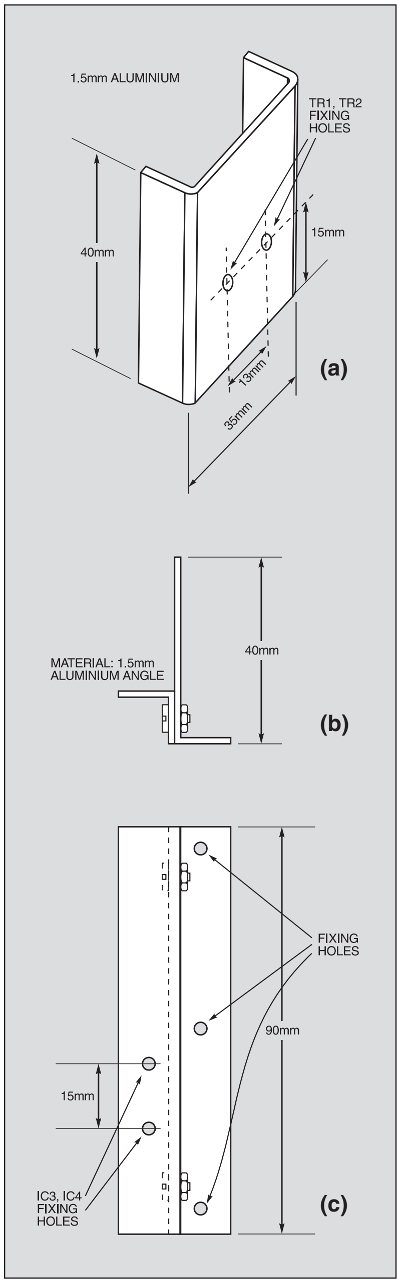


Fig.3. Dimensions and constructional details of the two heatsinks

SOLID-STATE VALVE POWER SUPPLY – CIRCUIT BOARD CONSTRUCTION

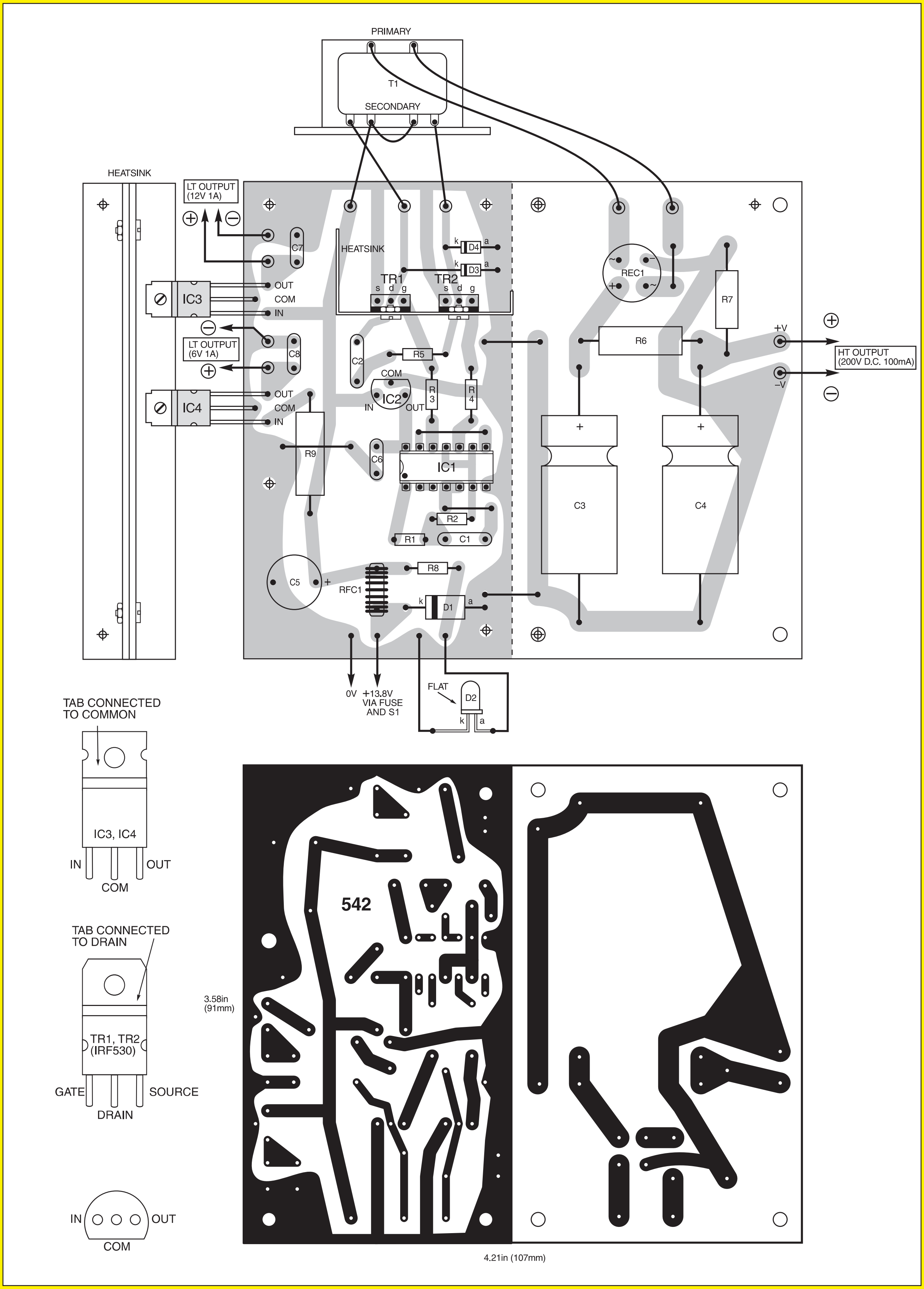
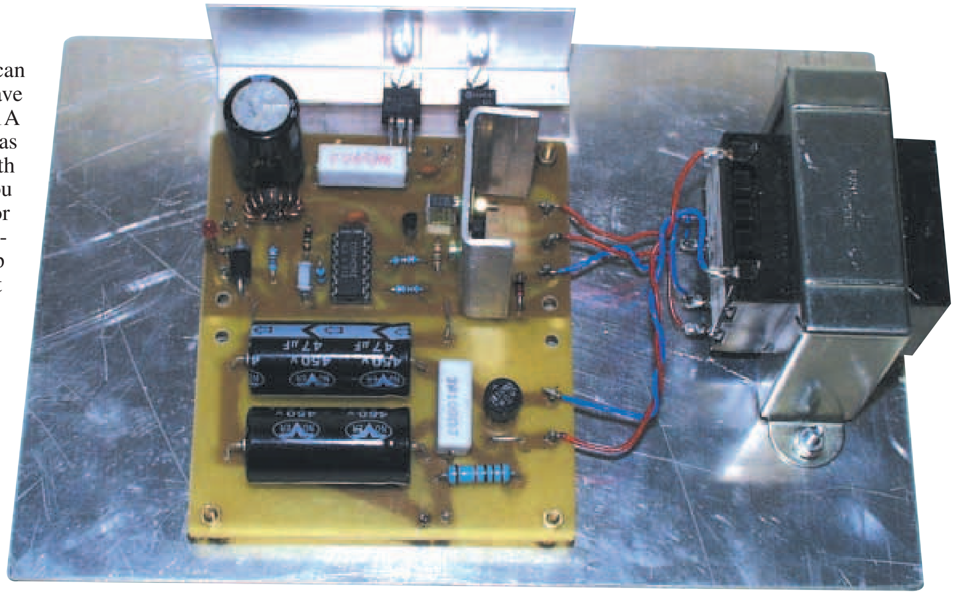


Fig.2. Printed circuit board component layout, wiring and full-size p.c.b. master for the Solid-State Valve PSU

Choosing A Transformer

The beauty of this p.s.u. is that you can try almost any mains transformer you have to hand for T1. A mains to 12V + 12V 1A transformer from the "spares" box was used in the prototype unit. It's worth experimenting with any transformers you already have, try a 6V + 6V, 9V + 9V or 15V + 15V type and see what HT voltage you get. When experimenting, keep an eye on the supply current the unit takes and switch off quickly if it gets much beyond 3A.

Although the transformer used in the prototype had a single mains primary winding, it is very common now to have two windings on the "mains" side, each marked 120V. This allows these mains transformers to be used on 120V mains (with the windings in parallel) or on 240V mains (as in the UK) with the windings in series. For this application the windings will need to be connected in series, as shown in the circuit diagram Fig.1.



Completed Valve Power Supply circuit board and transformer bolted to the aluminium chasis plate. The high wattage resistors bodies should be mounted clear of the board surface

Testing

No setting up procedure is needed, but this section covers testing to make sure the p.c.b. has been assembled without error and the external connections have been made correctly. Testing assumes that a variable voltage d.c. "bench" power supply is available, capable of supplying up to about 14V at 2A. This gives a "softer" testing routine where faults can be spotted and fixed before any major damage has been done.

Double-check the locations and polarities of the components on the board and check that all the solder joints are good, with no solder bridges or shorts appearing on any of the underside copper tracks/pads. Check the wiring from the p.c.b. to the transformer.

Powering Up

Before connecting an external d.c. power supply to the unit, check that it is set to 6V and that it is connected the right way round. Remember that diode D1 and fuse FS1 are there to protect the unit from incorrect polarity on the supply, but you should not test this to the extreme.

Now switch on the external supply and check that l.e.d. D2 lights. The current from the external supply (set to 6V) should be about 200mA with no load (other than resistor R7) across the HT terminal pins. If the current looks OK, but the l.e.d. does not light, the chances are you've wired it the wrong way round so simply reverse the connections and all should be well. If the current is excessive switch off quickly and reinvestigate the p.c.b. and external wiring.

Check the voltage on pin 14 of IC1: this should be 5V. If you have an oscilloscope or frequency meter available, check that IC1 is oscillating at around 50Hz.

Turning Up The Volts

If everything checks out satisfactorily, increase the external supply voltage towards 13·8V, keeping an eye on the current. The prototype took about 400mA at 13·8V with no external load on the HT or LT output terminals. Now check that the two LT outputs are close to the required 6V and 12V outputs. Because the two regulators (IC3 and IC4) are fixed-voltage types, no setting up or trimming is required.

Now measure the HT voltage: this should be about 200V. Check that it decays to zero in about 10 seconds when the external supply is disconnected or switched off.

The HT output can now be loaded and the output regulation checked. Using a combination of series connected 1kΩ 10W resistors as "dummy loads", the prototype produced the following HT results: two in series produced 100mA; three in series 67mA and four resulted in 50mA. Remember that 200V at 100mA equals 20W and so these resistors get very hot, so don't burn yourself! The following section on Regulation below shows the HT voltages measured for various loads, and the current taken from the external supply.

You can now add loads to these LT outputs and the voltages should remain stable up to an output current of 1A. Note that if you take 1A from an LT output, then an extra 1A will be taken from the external supply.

Once everything seems OK, you can move over to a 13·8V stabilized power supply if this is what you intend to use for your final power source. These supplies are usually current limited so any serious faults on the Valve P.S.U. should cause the external supply to shut down.

Regulation

With a 13·8V external supply, the unit produced the following HT voltages:

HT Load	*HT (V)*
0mA	215
46mA	210
67mA	202
93mA	186

Current from the 13·8V supply ranged from 400mA (at no load on HT) to 2·1A (at a 93mA load), giving an efficiency of about 61% at full load. Note that this current is with no load on the LT terminals.

At 100mA output current, the HT output had about a 1V peak-to-peak ripple at 50Hz. This amount of ripple will easily be removed by the decoupling on the HT line of the valve equipment being powered.

With a fixed two kilohm load across the HT terminals, varying the input d.c. voltage produced the following HT voltages:

D.C. Supply	*HT(V)*
6V	80V
8V	105V
10V	135V
12V	164V

It can be seen that this is a good way of reducing the HT output voltage should a voltage lower than 200V be needed.

LT Outputs

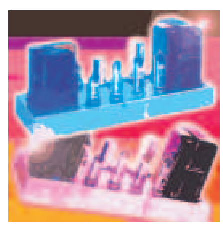
The 1A regulators used for IC3 and IC4 are suitable for supplying a total of three 6·3V valve heaters (remember that 6·3V heaters typically take 300mA) or six 12·6V valve heaters (each at 150mA). There is a pin-compatible range of 2A regulators available, namely the 78Sxx range.

If you anticipate taking more than 1A from the 6V LT terminal, be careful to heatsink IC4 correctly and re-calculate the value of resistor R9 to share the power dissipation evenly.

Connecting Up

To connect to the valve equipment being powered, you can either connect directly to the pins on the p.c.b., or fit a connector so the p.s.u. can be separated from the valve equipment if needed. It is a good idea to use some sort of a shrouded connector for the HT terminal to prevent accidental contact.

It might also be wise to fit an in-line fuse-holder and 100mA fuse in the HT positive lead in case of shorts in the valve equipment. □



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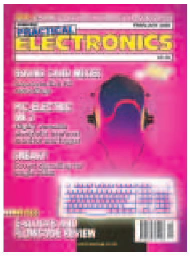

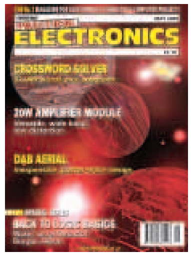

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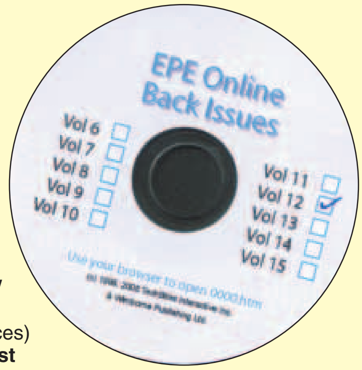

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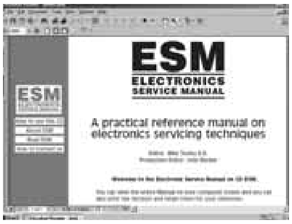

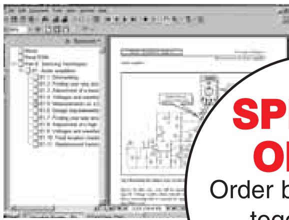

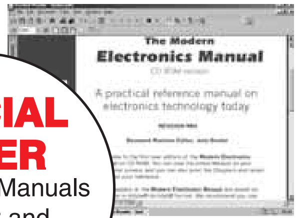

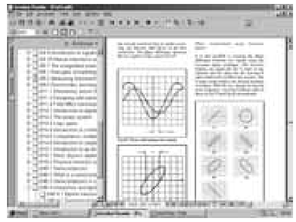

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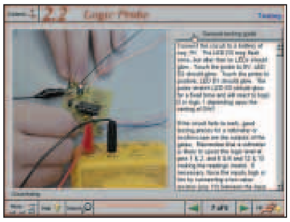

Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture**, **circuit simulation** and **p.c.b. design** software is included.
The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

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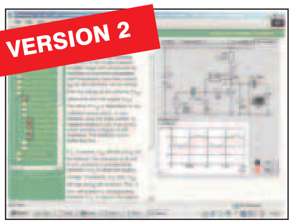

Circuit simulation screen

Provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 2 has been considerably expanded in almost every area following a review of major syllabuses (GCSE, GNVQ, A level and HNC). It also contains both European and American circuit symbols. Sections include: ***Fundamentals:*** units & multiples, electricity, electric circuits, alternating circuits. ***Passive Components:*** resistors, capacitors, inductors, transformers. ***Semiconductors:*** diodes, transistors, op.amps, logic gates. ***Passive Circuits. Active Circuits.*** *The Parts Gallery* will help students to recognise common electronic components and their corresponding symbols in circuit diagrams. Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

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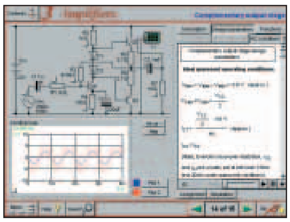

Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.
Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections),Transistors (4 sections), Waveshaping Circuits (6 sections). **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

DIGITAL ELECTRONICS V2.0

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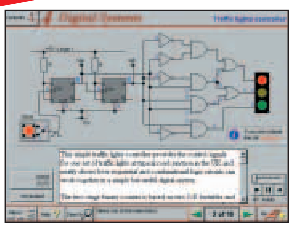

Virtual laboratory – Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.
Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

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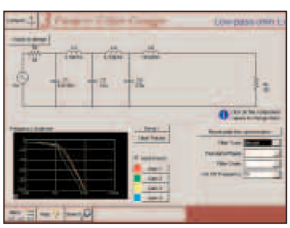

Filter synthesis

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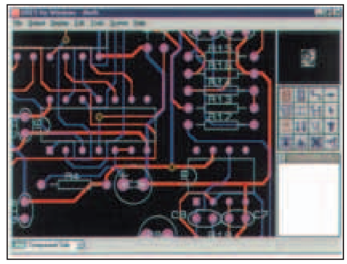

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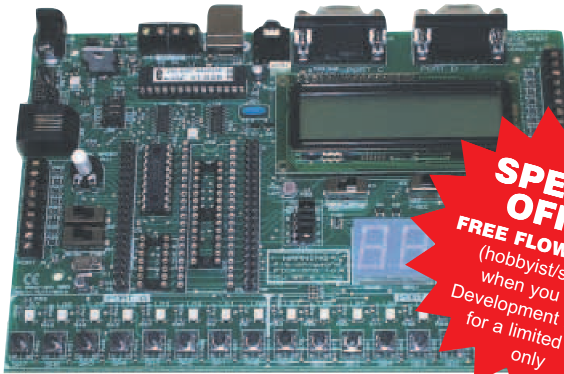

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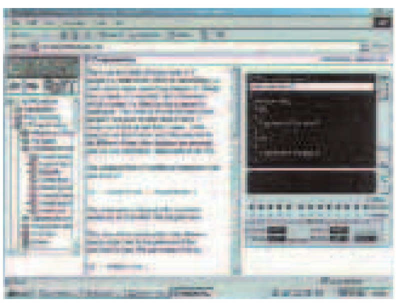

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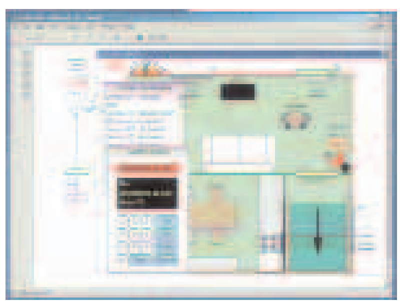

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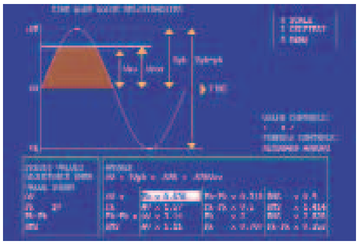

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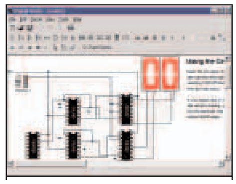

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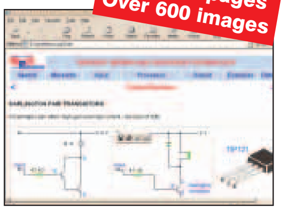

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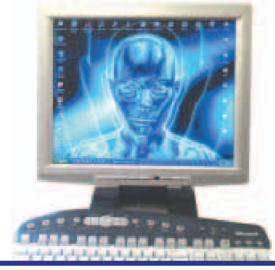

Robert Penfold

ADDING MORE INPUTS TO AN A/D CONVERTER

THE previous *Interface* articles covered circuits using parallel digital-to-analogue and analogue-to-digital converters. Using a single parallel converter with the printer port of a PC is easy enough, since there are plenty of lines for use with one converter. Some applications require two or more analogue inputs or outputs, and things then become a bit more complicated.

Using serial converters offers a possible solution, but there could still be a lack of lines of the required type. Even with sufficient input/output lines available, the software side of things could become quite complicated.

A possible solution is to using a simple multiplexing technique to provide extra digital input and (or) output lines. However, any system that uses several converters has the drawback of being expensive. "Cheap as chips" is not really an apt description of most converter chips, which are generally quite expensive. A system that uses several of them will inevitably be quite pricey.

Analogue Multiplexing

The usual way around the problem is to use one converter and analogue multiplexing. You need some additional outputs to control the analogue multiplexer, but there will usually be at least one or two otherwise unused outputs available. The PC's printer port has four handshake outputs as well as the eight data outputs. Even if a couple of outputs are used as handshake lines for the converter itself, there will still be some lines available for other purposes such as controlling a multiplexer.

There is a potential drawback in using one converter to provide several analogue inputs or outputs. This is the reduction in speed that is likely to occur.

Speed will probably not be a problem with digital-to-analogue conversion, since even "bog standard" circuits of this type achieve very rapid conversions. It is more likely to be an issue with analogue-to-digital conversion, where the conversion times tend to be relatively long.

Where a converter can provide (say) 50,000 conversions per second, the conversion rate becomes just 10,000 per second for each channel if there are five inputs. A separate conversion has to be carried out for each channel, one after the other. Where the relative lack of speed will not be a problem, using a single converter will almost certainly be the more cost-effective solution

Four Into One

An analogue switch and some control lines are all that is required in order to add more inputs to an analogue-to-digital converter. There are various types of analogue switch, and some of them are primarily intended for use in high quality audio systems. Some of these might work well in the present application, but their high cost makes them a dubious choice.

However, CMOS analogue switches have characteristics that make them well suited to this application and they are relatively cheap. The 4066BE, for instance, is a quad s.p.s.t. switch, and with the aid of four control lines it can provide an analogue-to-digital converter with four inputs.

The circuit diagram of Fig.1 shows how this can be achieved. Each switch in the 4066BE has its own control input, which is taken high (logic 1) to turn the switch on, or low (logic 0) to turn it off.

The resistance through one of these switches is extremely high in the "off" state but is only about 100 ohms in the "on" state. In order to select an input so that it can be read, it is merely necessary to take the relevant control input high while holding the other three low. For example, to select Input 2 it is necessary to take pin 5 of IC1 high while holding pins 6, 12, and 13 low.

In this case the four control inputs are connected to the four handshake outputs of the PC's printer port. An important point to bear in mind here is that the output at pin 16 is not inverted but the other three are inverted. Table 1 shows the values needed to select each input.

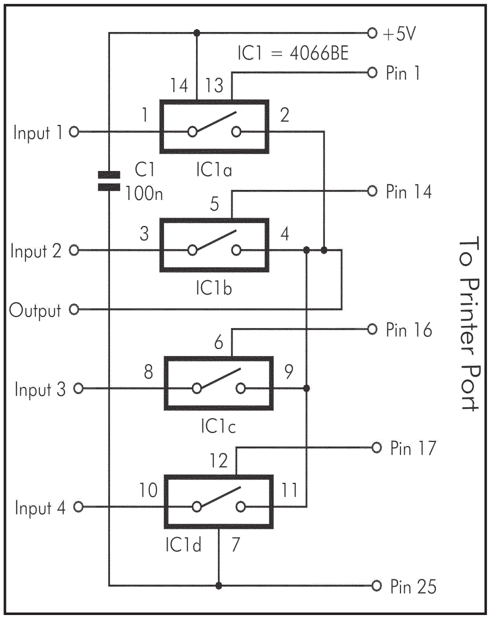

Fig.1. A CMOS quad analogue switch i.c. can provide an anologue-to-digital converter with four inputs

Table 1: Values needed for each input

Value Output	*Input Selected*
11	None
10	Input 1
9	Input 2
15	Input 3
3	Input 4

Settling-In Period

Although the circuit operates very rapidly, with anything like this it is advisable to allow a brief settling time so that the input voltage to the converter is valid by the time the conversion is started. It is not usually necessary to insert a delay of a few microseconds when using a high-level language such as Visual BASIC, since the relative slowness of the program will provide a suitable delay. However, a programmed delay might be required when using a fast language such as assembler.

The "on" resistance through a switch could be enough to produce a significant voltage drop through the switch, but this is unlikely to occur. The input resistance of most analogue-to-digital converter chips is many megohms, giving a negligible voltage drop. However, if necessary, it should be possible to compensate for any slight voltage reduction in the setting up procedure or in the software. It is generally best if the switching circuit is added immediately ahead of the converter chip, and after any signal conditioning. This way it is dealing with a low-level signal that is within the limits of the 5V supply. It will not work properly with signals that go outside these limits.

The drawback of this method is that any signal conditioning, such as amplification or level shifting has to be duplicated for each input. In some cases the signal conditioning will be different for each input anyway, but it will have to be duplicated even where it is the same for each channel.

Two Into One

There is a slight problem with the circuit of Fig.1 in that it requires four output lines from the PC, and that is all the printer port has to offer. This is fine if handshake outputs are not needed for other purposes, but it is likely that at least one will be required as part of the control system for the converter chip. The circuit can still be used if only two or three outputs are available. However, only two or three switches can then be used, giving two or three analogue inputs.

It is still possible to have two inputs using a single converter even if there is just one spare output line. A simple circuit that achieves this is shown in Fig.2. The output line of the PC is used to control IC1a directly, but IC1b is controlled via an inverter. In

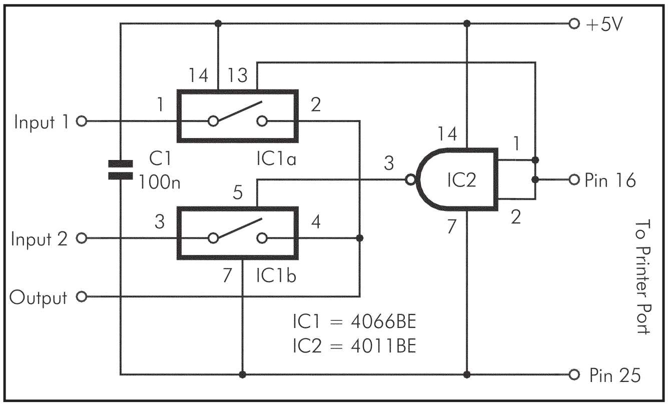

Fig.2. This circuit provides two inputs but requires just one control line. IC2 is a NAND gate wired to act as a simple inverter – see text

this example the inverter is actually a two input NAND gate wired to act as an inverter, but the circuit will work properly using an inverting buffer or any other form of CMOS compatible inverter.

When the output line of the PC is set high, IC1a is switched on, but IC1b is switched off because it receives a low control level from the inverter. Setting the output line low reverses the situation, with IC1a being turned off and IC1b being turned on. In other words, the two switches give a simple changeover action, with a low control level selecting Input 2 and a high control level selecting Input 1.

With the suggested method of connection the circuit is controlled by the Strobe output of the printer port at pin 1. This output is obtained via an integral inverting buffer, so writing a value of 0 to the handshake output register selects Input 1, and using a value of 1 selects Input 2.

Counting Up

In theory at any rate, using one or two handshake outputs it is possible to have any number of inputs by having a control circuit that is based on a form of counter. The circuit of Fig.3 provides four inputs and uses a single output of a PC's printer port. The switching part of the circuit is essentially the same as the one in Fig.1, but the control inputs are fed from outputs 0 to 3 of IC2. The latter is a 1 of 10 decoder, and it has ten outputs that go high, in sequence, under the control of a clock signal applied to pin 14.

At switch-on a reset pulse is supplied to pin 15 of IC2 by C2 and R3. The Reset input is actually driven from this circuit and output 4 of IC2 via a simple OR gate based on diode D1 and D2. Either of these sources going high will reset IC2 and send output 0 high. Initially then, IC2 is reset, output 0 is high, IC1a is switched on, and Input 1 is selected. The other outputs of IC2 are low, and the other three switches are "off".

The Clock input of IC2 is fed from a handshake output of the printer port, and generating a pulse on this line sends output 0 low and output 1 high. This turns IC1b "on" and IC1a "off", so that Input 2 is selected in place of Input 1.

Generating further clock pulses results in IC1c switching on and Input 3 being selected instead of Input 2. Then IC1d switches on and Input 4 is selected in place of Input 3. Output 4 goes high on the next clock pulse, which resets IC2 and takes output 0 high again, with Input 1 being selected as a result. By supplying clock pulses to IC2 it is therefore possible to select each input in turn.

More switches/inputs can be accommodated by using further outputs of IC2, and connecting the anode of diode D1 to the appropriate output pin. Of course, R1 and D1 are not needed if all ten outputs are used to control switches, because IC2 will cycle back to zero on the next clock pulse anyway.

Ideally, the Reset input of IC2 would be driven from a second output of the printer port. Components C2, R1, R2, R3, D1, and D2 would then be omitted, and the Reset input of IC2 would then be driven direct from the output line. The advantage of this method is that there is no risk of the count getting "out of sync".

For example, as things stand, if there are any spurious clock pulses generated during the computer's boot-up sequence, the count will not start from the right place. With the Reset input under direct control of the computer, the circuit can be reset before each set of readings is taken. This ensures that the counter always starts at zero and eliminates the risk of the circuit drifting out of synchronization.

Multiple Outputs

So far we have only considered the use of analogue switches to provide additional inputs for an analogue-to-digital converter. It is possible to use these circuits the other way around so that a digital-to-analogue converter is provided with more outputs, but there is a slight complication. Unless some additional circuitry is used, each output will only be valid while its switch is activated. The rest of the time it will simply be left floating, which is not acceptable in most practical applications.

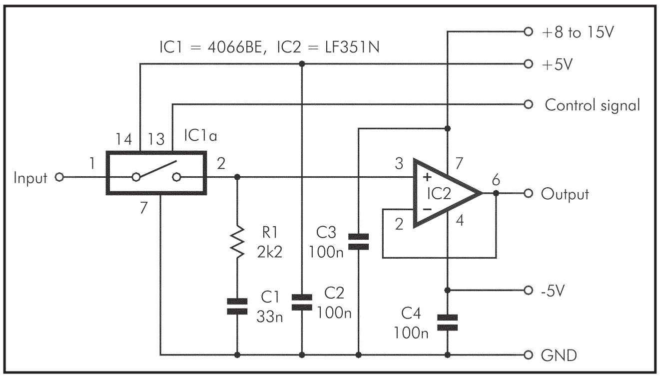

Fig.4. Providing additional outputs for a digital-to-analogue converter requires a sample and hold circuit rather than a simple switch

In order to maintain a valid output voltage it is merely necessary to use a basic sample and hold circuit (Fig.4). An operational amplifier, IC2, is used here as a simple voltage follower. The charge on capacitor C1 is used to maintain the output voltage when the electronic switch (IC1) is turned off. The charge on C1 will gradually decay, but the rate of change will be very slow because IC2 has an extremely high input resistance.

The length of time that a valid output level will be maintained is something of an unknown quantity that is governed by factors such as the leakage resistance of C1 and leakage resistances in the circuit board. Updating each sample and hold circuit every few seconds should be sufficient to ensure that accurate results are maintained.

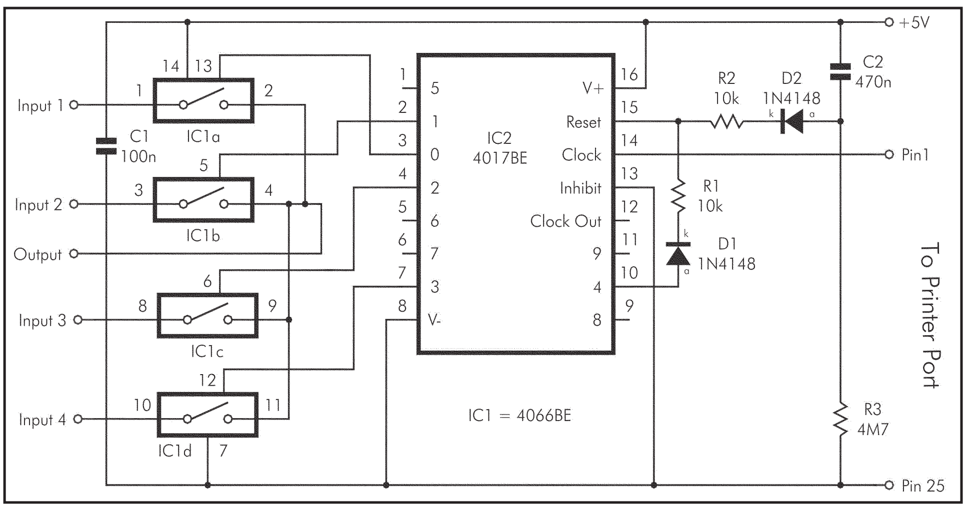

Fig.3. Based on a form of counter, IC2, this circuit provides four inputs but has only one control input (IC2 pin 14). It can be expanded to handle up to ten inputs

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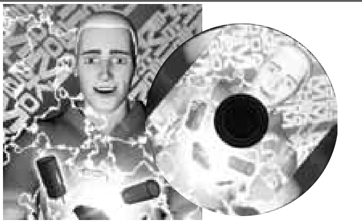

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This book first covers the basics of simple logic circuits in general, and then progresses to specific TTL logic integrated circuits. The devices covered include gates, oscillators, timers, flip/flops, dividers, and decoder circuits. Some practical circuits are used to illustrate the use of TTL devices in the "real world".

142 pages **Order code BP332** **£5.45**

PRACTICAL ELECTRONICS CALCULATIONS AND FORMULAE
F. A. Wilson, C.G.I.A., C.Eng., F.I.E.E., F.I.E.R.E., F.B.I.M.

Bridges the gap between complicated technical theory, and "cut-and-tried" methods which may bring success in design but leave the experimenter unfulfilled. A strong practical bias – tedious and higher mathematics have been avoided where possible and many tables have been included.

The book is divided into six basic sections: Units and Constants, Direct-Current Circuits, Passive Components, Alternating-Current Circuits, Networks and Theorems, Measurements.

256 pages **Order code BP53** **£5.49**

MICROCONTROLLER COOKBOOK
Mike James

The practical solutions to real problems shown in this cookbook provide the basis to make PIC and 8051 devices really work. Capabilities of the variants are examined, and ways to enhance these are shown. A survey of common interface devices, and a description of programming models, lead on to a section on development techniques. The cookbook offers an introduction that will allow any user, novice or experienced, to make the most of microcontrollers.

240 pages **Order code NE26** **£23.99**

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

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Computing & Robotics

WINDOWS XP EXPLAINED
N. Kantaris and P. R. M. Oliver

If you want to know what to do next when confronted with Microsoft's Windows XP screen, then this book is for you. It applies to both the Professional and Home editions.

The book was written with the non-expert, busy person in mind. It explains what hardware requirements you need in order to run Windows XP successfully, and gives an overview of the Windows XP environment.

The book explains: How to manipulate Windows, and how to use the Control Panel to add or change your printer, and control your display; How to control information using WordPad, Notepad and Paint, and how to use the Clipboard facility to transfer information between Windows applications; How to be in control of your filing system using Windows Explorer and My Computer; How to control printers, fonts, characters, multimedia and images, and how to add hardware and software to your system; How to configure your system to communicate with the outside world, and use Outlook Express for all your email requirements; How to use the Windows Media Player 8 to play your CDs, burn CDs with your favourite tracks, use the Radio Tuner, transfer your videos to your PC, and how to use the Sound Recorder and Movie Maker; How to use the System Tools to restore your system to a previously working state, using Microsoft's Website to update your Windows set-up, how to clean up, defragment and scan your hard disk, and how to backup and restore your data; How to successfully transfer text from those old but cherished MS-DOS programs.

268 pages **Order code BP514** **£7.99**

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS
Robert Penfold

Shows the reader how to build a variety of increasingly sophisticated computer controlled robots using the brilliant Lego Mindstorms Robotic Invention System (RIS). Initially covers fundamental building techniques and mechanics needed to construct strong and efficient robots using the various "click-together" components supplied in the basic RIS kit. Explains in simple terms how the "brain" of the robot may be programmed on screen using a PC and "zapped" to the robot over an infra-red link. Also, shows how a more sophisticated Windows programming language such as Visual BASIC may be used to control the robots.

Detailed building and programming instructions provided, including numerous step-by-step photographs.

288 pages – large format **Order code BP901** **£14.99**

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Covers the Vision Command System

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using Lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with 'waiter service' when you clap your hands, perform tricks, 'see' and avoid objects by using 'bats radar', or accurately follow a line marked on the floor. Learn to use additional types of sensors including rotation, light, temperature, sound and ultrasonic and also explore the possibilities provided by using an additional (third) motor. For the less experienced, RCX code programs accompany most of the featured robots. However, the more adventurous reader is also shown how to write programs using Microsoft's VisualBASIC running with the ActiveX control (Spirit.OCX) that is provided with the RIS kit.

Detailed building instructions are provided for the featured robots, including numerous step-by-step photographs. The designs include rover vehicles, a virtual pet, a robot arm, an 'intelligent' sweet dispenser and a colour conscious robot that will try to grab objects of a specific colour.

298 pages **Order code BP902** **£14.99**

PIC YOUR PERSONAL INTRODUCTORY COURSE SECOND EDITION John Morton

Discover the potential of the PIC microcontroller through graded projects – this book could revolutionise your electronics construction work!

A uniquely concise and practical guide to getting up and running with the PIC Microcontroller. The PIC is one of the most popular of the microcontrollers that are transforming electronic project work and product design.

Assuming no prior knowledge of microcontrollers and introducing the PICs capabilities through simple projects, this book is ideal for use in schools and colleges. It is the ideal introduction for students, teachers, technicians and electronics enthusiasts. The step-by-step explanations make it ideal for self-study too: this is not a reference book – you start work with the PIC straight away.

The revised second edition covers the popular reprogrammable EEPROM PICs: P16C84/16F84 as well as the P54 and P71 families.

270 pages **Order code NE36** **£16.99**

INTRODUCTION TO MICROPROCESSORS
John Crisp

If you are, or soon will be, involved in the use of microprocessors, this practical introduction is essential reading. This book provides a thoroughly readable introduction to microprocessors. assuming no previous knowledge of the subject, nor a technical or mathematical background. It is suitable for students, technicians, engineers and hobbyists, and covers the full range of modern microprocessors.

After a thorough introduction to the subject, ideas are developed progressively in a well-structured format. All technical terms are carefully introduced and subjects which have proved difficult, for example 2's complement, are clearly explained. John Crisp covers the complete range of microprocessors from the popular 4-bit and 8-bit designs to today's super-fast 32-bit and 64-bit versions that power PCs and engine management systems etc.

222 pages **Order code NE31** **£21.99**

EASY PC CASE MODDING
R.A Penfold

Why not turn that anonymous grey tower, that is the heart of your computer system, into a source of visual wonderment and fascination. To start, you need to change the case or some case panels for ones that are transparent. This will then allow the inside of your computer and it's working parts to be clearly visible.

There are now numerous accessories that are relatively inexpensive and freely available, for those wishing to customise their PC with added colour and light. Cables and fans can be made to glow, interior lights can be added, and it can all be seen to good effect through the transparent case. Exterior lighting and many other attractive accessories may also be fitted.

This, in essence, is case modding or PC Customising as it is sometimes called and this book provides all the practical details you need for using the main types of case modding components including:- Electro luminescent (EL) 'go-faster' stripes: Internal lighting units: Fancy EL panels: Data cables with built-in lighting: Data cables that glow with the aid of 'black' light from an ultraviolet (UV) tube: Digital display panels: LED case and heatsink fans: Coloured power supply covers.

192 pages **Order code BP542** **£8.99**

NEWNES PC TROUBLESHOOTING POCKET BOOK – THIRD EDITION
Howard Anderson, Mike Tooley

All the essential data for PC fault-finding and upgrading. This book provides a concise and compact reference that describes, in a clear and straightforward manner, the principles and practice of fault-finding and upgrading PCs and peripherals. The book is aimed at anyone who is involved with the installation, configuration, maintenance, upgrading, repair or support of PC systems. It also provides non-technical users with sufficient background information, charts and checklists to enable the diagnosis of faults and help to carry out simple modifications and repairs. In order to reflect rapid changes in computer technology (both hardware and software) this new edition has been completely revised and rewritten.

256 pages **Order code NE41** **£19.99**

NEWNES INTERFACING COMPANION
Tony Fischer-Cripps

A uniquely concise and practical guide to the hardware, applications and design issues involved in computer interfacing and the use of transducers and instrumentation.

Newnes Interfacing Companion presents the essential information needed to design a PC-based interfacing system from the selection of suitable transducers, to collection of data, and the appropriate signal processing and conditioning.

Contents: Part 1 – Transducers; Measurement systems; Temperature; Light; Position and motion; Force, pressure and flow. Part 2 – Interfacing; Number systems; Computer architecture; Assembly language; Interfacing; A to D and D to A conversions; Data communications; Programmable logic controllers; Data acquisition project. Part 3 – Signal processing; Transfer function; Active filters; Instrumentation amplifier; Noise; Digital signal processing.

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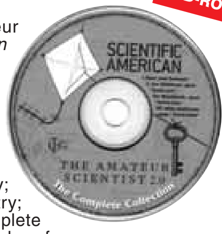

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BEBOP BYTES BACK (and the Beboputer Computer Simulator) CD-ROM
Clive (Max) Maxfield and Alvin Brown

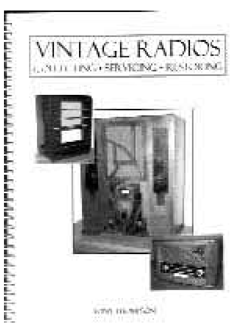
CD-ROM

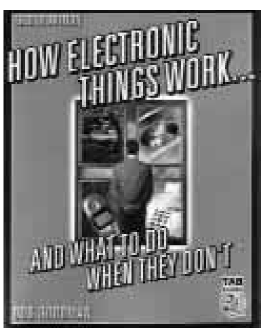
This follow-on to *Bebop to the Boolean Boogie* is a multimedia extravaganza of information about how computers work. It picks up where “Bebop I” left off, guiding you through the fascinating world of computer design . . . and you’ll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the CD-ROM contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the CD-ROM contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers. If you’re the slightest bit interested in the inner workings of computers, then don’t dare to miss this!
Over 800 pages in Adobe Acrobat format **Order code BEB2 CD-ROM** **£21.95**

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold
This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.
In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.
96 pages **Order code BP239** **£5.49**

OSCILLOSCOPES – FIFTH EDITION
Ian Hickman
Oscilloscopes are essential tools for checking circuit operation and diagnosing faults, and an enormous range of models are available.
This handy guide to oscilloscopes is essential reading for anyone who has to use a ’scope for their work or hobby; electronics designers, technicians, anyone in industry involved in test and measurement, electronics enthusiasts . . . Ian Hickman’s review of all the latest types of ’scope currently available will prove especially useful for anyone planning to buy – or even build – an oscilloscope.
The contents include a description of the basic oscillscope; Advanced real-time oscilloscope; Accessories; Using oscilloscopes; Sampling oscilloscopes; Digital storage oscilloscopes; Oscilloscopes for special purposes; How oscillocopes work (1): the CRT; How oscilloscopes work (2): circuitry; How oscilloscopes work (3): storage CRTs; plus a listing of Oscilloscope manufacturers and suppliers.
288 pages **Order code NE37** **£22.99**

PRACTICAL ELECTRONIC FAULT FINDING AND TROUBLESHOOTING
Robin Pain
To be a real fault finder, you must be able to get a feel for what is going on in the circuit you are examining. In this book Robin Pain explains the basic techniques needed to be a fault finder.





Simple circuit examples are used to illustrate principles and concepts fundamental to the process of fault finding. This is not a book of theory, it is a book of practical tips, hints and rules of thumb, all of which will equip the reader to tackle any job. You may be an engineer or technician in search of information and guidance, a college student, a hobbyist building a project from a magazine, or simply a keen self-taught amateur who is interested in electronic fault finding but finds books on the subject too mathematical or specialised.
The fundamental principles of analogue and digital fault finding are described (although, of course, there is no such thing as a “digital fault” – all faults are by nature analogue). This book is written entirely for a fault finder using only the basic fault-finding equipment: a digital multimeter and an oscilloscope. The treatment is non-mathematical (apart from Ohm’s law) and all jargon is strictly avoided.
274 pages **Order code NE22** **£25.99**

ELECTRONIC TEST EQUIPMENT HANDBOOK
Steve Money
In most applications of electronics, test instruments are essential for checking the performance of a system or for diagnosing faults in operation, and so it is important for engineers, technicians, students and hobbyists to understand how the basic test instruments work and how they can be used.
The principles of operation of the various types of test instrument are explained in simple terms with a minimum of mathematical analysis. The book covers analogue and digital meters, bridges, oscilloscopes, signal generators, counters, timers and frequency measurement. The practical uses of these instruments are also examined.
206 pages **Order code PC109** **£9.95**

DIGITAL GATES AND FLIP-FLOPS
Ian R. Sinclair
This book, intended for enthusiasts, students and technicians, seeks to establish a firm foundation in digital electronics by treating the topics of gates and flip-flops thoroughly and from the beginning.
Topics such as Boolean algebra and Karnaugh mapping are explainend, demonstrated and used extensively, and more attention is paid to the subject of synchronous counters than to the simple but less important ripple counters.
No background other than a basic knowledge of electronics is assumed, and the more theoretical topics are explained from the beginning, as also are many working practices. The book concludes with an explanation of microprocessor techniques as applied to digital logic.
200 pages **Order code PC106** **£9.95**

UNDERSTANDING ELECTRONIC CONTROL SYSTEMS
Owen Bishop
Owen Bishop has produced a concise, readable text to introduce a wide range of students, technicians and professionals to an important area of electronics. Control is a highly mathematical subject, but here maths is kept to a minimum, with flow charts to illustrate principles and techniques instead of equations.
Cutting edge topics such as microcontrollers, neural networks and fuzzy control are all here, making this an ideal refresher course for those working in Industry. Basic principles, control algorithms and hardwired control systems are also fully covered so the resulting book is a comprehensive text and well suited to college courses or background reading for university students.
The text is supported by questions under the headings Keeping Up and Test Your Knowledge so that the reader can develop a sound understanding and the ability to apply the techniques they are learning.
228 pages **Order code NE35** **£20.99**

HOW ELECTRONIC THINGS WORK – AND WHAT TO DO WHEN THEY DON’T
Robert Goodman
You never again have to be flummoxed, flustered or taken for a ride by a piece of electronics equipment. With this fully illustrated, simple-to-use guide, you will get a grasp on the workings of the electronic world that surrounds you – and even learn to make your own repairs.
You don’t need any technical experience. This book gives you: Clear explanations of how things work, written in everyday language. Easy-to-follow, illustrated instructions on using test equipment to diagnose problems. Guidelines to help you decide for or against professional repair. Tips on protecting your expensive equipment from lightning and other electrical damage. Lubrication and maintenance suggestions.
Covers: colour TVs, VCRs, radios, PCs, CD players, printers, telephones, monitors, camcorders, satellite dishes, and much more!
394 pages **Order code MGH3** **£21.99**

VINTAGE RADIOS – COLLECTING ● SERVICING ● RESTORING
Tony Thompson
The essential guide to collecting, repairing and restoring vintage valve radios. These receivers are becoming ever more popular as collectibles, this is a good thing because it means that a very large piece of technological history is being reclaimed when at one time many thought it lost forever. If you look around, you will find plenty of valve radio sets just waiting for a loving restoration. They may not yet be the most highly prized, and they are unlikely to be in top condition, but they can be yours and, if you develop the skills outlined in this book, you will possess radio receivers to be proud of.
The book covers radio history, styling, faultfinding, chassis and cabinet restoration, types of set.
124 pages spiral bound **Order code TT1** **£13.50**

All prices include UK P&P

Project Building

ELECTRONIC PROJECT BUILDING FOR BEGINNERS
R. A. Penfold

This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:

Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.

In fact everything you need to know in order to get started in this absorbing and creative hobby.

135 pages **Order code BP392** **£5.49**

BUILDING VALVE AMPLIFIERS
Morgan Jones

The practical guide to building, modifying, fault-finding and repairing valve amplifiers. A hands-on approach to valve electronics – classic and modern – with a minimum of theory. Planning, fault-finding, and testing are each illustrated by step-by-step examples.

A unique hands-on guide for anyone working with valve (*tube* in USA) audio equipment – as an electronics experimenter, audiophile or audio engineer.

Particular attention has been paid to answering questions commonly asked by newcomers to the world of the vacuum tube, whether audio enthusiasts tackling their first build, or more experienced amplifier designers seeking to learn the ropes of working with valves. The practical side of this book is reinforced by numerous clear illustrations throughout.

368 pages **Order code NE40** **£21.99**

STARTING ELECTRONICS, THIRD EDITION
KEITH BRINDLEY

A punchy practical introduction to self-build electronics. The ideal starting point for home experimenters, technicians and students who want to develop the real hands-on skills of electronics construction.

A highly practical introduction for hobbyists, students, and technicians. Keith Brindley introduces readers to the functions of the main component types, their uses, and the basic principles of building and designing electronic circuits.

Breadboarding layouts make this very much a ready-to-run book for the experimenter, and the use of multimeter, but not oscilloscopes, and readily available, inexpensive components makes the practical work achievable in a home or school setting as well as a fully equiped lab.

288 pages **Order code NE42** **£10.99**

ELECTRONIC PROJECTS FOR EXPERIMENTERS
R. A. Penfold

Many electronic hobbyists who have been pursuing their hobby for a number of years seem to suffer from the dreaded "seen it all before" syndrome. This book is fairly and squarely aimed at sufferers of this complaint, plus any other electronics enthusiasts who yearn to try something a bit different.

The subjects covered include:- Magnetic field detector, Basic Hall effect compass, Hall effect audio isolator, Voice scrambler/descrambler, Bat detector, Bat style echo location, Noise cancelling, LED stroboscope, Infra-red "torch", Electronic breeze detector, Class D power amplifier, Strain gauge amplifier, Super hearing aid.

138 pages **Order code BP371** **£5.45**

PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold

While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.

The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.

All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.

132 pages **Order code BP374** **£5.45**

ELECTRONIC MUSIC AND MIDI PROJECTS
R. A. Penfold

Whether you wish to save money, boldly go where no musician has gone before, rekindle the pioneering spirit, or simply have fun building some electronic music gadgets, the designs featured in this book should suit your needs. The projects are all easy to build, and some are so simple that even complete beginners at electronic project construction can tackle them with ease. Stripboard layouts are provided for every project, together with a wiring diagram. The mechanical side of construction has largely been left to the individual constructors to sort out, simply because the vast majority of project builders prefer to do their own thing.

None of the designs requires the use of any test equipment in order to get them set up properly. Where any setting up is required, the procedures are very straightforward, and they are described in detail.

Projects covered: Simple MIDI tester, Message grabber, Byte grabber, THRU box, MIDI auto switcher, Auto/manual switcher, Manual switcher, MIDI patchbay, MIDI controlled switcher, MIDI lead tester, Program change pedal, Improved program change pedal, Basic mixer, Stereo mixer, Electronic swell pedal, Metronome, Analogue echo unit.

138 pages **Order code PC116** **£5.45**

VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR
R. A. Penfold

Written by highly respected author R. A. Penfold, this book contains a collection of electronic projects specially designed for video enthusiasts. All the projects can be simply constructed, and most are suitable for the newcomer to project construction, as they are assembled on stripboard.

There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.

Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, pushbutton fader, computer control interface, 12 volt mains power supply.

124 pages **Order code PC115** **£5.45**

Theory and Reference

COIL DESIGN AND CONSTRUCTIONAL MANUAL
B. B. Babani

A complete book for the home constructor on "how to make" RF, IF, audio and power coils, chokes and transformers. Practically every possible type is discussed and calculations necessary are given and explained in detail. Although this book is now twenty years old, with the exception of toroids and pulse transformers little has changed in coil design since it was written.

96 pages **Order code BP160** **£4.49**

PRACTICAL ELECTRONIC FILTERS
Owen Bishop

This book deals with the subject in a non-mathematical way. It reviews the main types of filter, explaining in simple terms how each type works and how it is used.

The book also presents a dozen filter-based projects with applications in and around the home or in the constructor's workshop. These include a number of audio projects such as a rythm sequencer and a multi-voiced electronic organ.

Concluding the book is a practical step-by-step guide to designing simple filters for a wide range of purposes, with circuit diagrams and worked examples.

188 pages **Order code BP299** **£5.49**

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PCB SERVICE

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NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

Back numbers or photocopies of articles are available if required – see the *Back Issues* page for details. We do not supply kits or components for our projects.

Please check price and availability in the latest issue.

A large number of older boards are listed on our website.

Boards can only be supplied on a payment with order basis.

PROJECT TITLE		Order Code	Cost
★PIC Quickstep	JUNE '04	448	£5.71
Body Detector MkII		449	£4.91
★Teach-In '04 Part 8 – **Software only**		–	–
★MIDI Synchronome – **Software only**		–	–
Hard Drive Warbler	JULY '04	450	£4.60
★Bongo Box		451	£6.02
Portable Mini Alarm – Sensor		452	£5.23
– Counter		453	£5.07
★Teach-In '04 Part 9			
PIC Combination Lock Alarm Monitor		454	£5.07
★EPE Magnetometry Logger		455	£5.71
Keyring L.E.D. Torch	AUG '04	456	£4.12
★Teach-In '04 Part 10 – PIC Curtain or Blind Winder		457	£5.39
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– Tone Control		459	£4.75
– Audio Power Amp (TDA2003)		347	£4.60
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EPE Wart Zapper	SEPT '04	464	£4.60
★Radio Control Failsafe		465	£4.76
★AlphaMouse Game		466	£4.60
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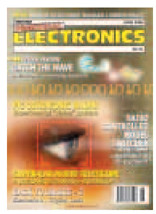

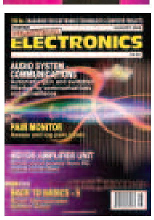
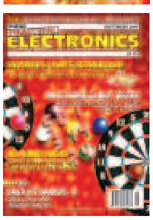


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